SEMICONDUCTOR PRODUCTS

THE Bendix CORPORATION

BENDIX SEMICONDUCTOR DIVISION, HOLMDEL, N. J.

PRODUCTION ENGINEERING MEASURE

QUARTERLY PROGRESS REPORT NO. 3

PRODUCTION RELIABILITY

IMPROVEMENT PROGRAM

FOR

GERMANIUM TRANSISTOR 2N1430

31 OCTOBER 1962 TO 31 JANUARY 1963

CONTRACT NO. DA-36-039-SC-86723

ORDER NO. 19045-PP-62-81-81

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PRODUCTION RELIABILITY IMPROVEMENT PROGRAM FOR GERMANIUM TRANSISTOR 2N1430

PRODUCTION ENGINEERING MEASURE

QUARTERLY REPORT NO. 3

31 OCTOBER 1962 TO 31 JANUARY 1963

OBJECT: To improve production techniques in order to increase the reliability and yield of the 2N1430 Germanium Transistor.

Contract No. DA-36-039-SC-86723

Order No. 19045-PP-62-81-81

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I - ABSTRACT

Planning in all areas under study has been completed.

Equipment set-up has been completed except in those areas where refinement modifications are necessary.

Previous control production runs have been evaluated and the affected areas of study have been finalized where possible. Additional studies are or have been initiated to standardize the remaining areas of interest.

II.- PURPOSE

The purpose of this measure is to:

1. Direct efforts toward improving production techniques to improve the reliability of the 2N1430 Germanium transistor using as an objective a maximum operating failure rate of 0.05% per 1000 hours at a 90% confidence level of 25°C.

2. Improve the areas of resistivity control, etch pit control, uniform penetration in diffusion, depth control in alloying, spreading and wetting in alloying, collector attachment, surface passivation, final preparation prior to sealing, gettering technique, and leak determination in order to approach the above objective.

3. Provide information and data to demonstrate the results in the areas of study.

4. Establish and maintain quality control measures to insure accuracy and reliability of the established process techniques.

1.1.1. Resistivity Control - F. Arden & H. Sivik

The study of certain growth conditions for preparing germanium crystals with tight radial and vertical resistivity gradients was continued in this quarter. Thirteen additional crystals were prepared utilizing both the N.R.C. and the floating crucible furnaces.

Nine crystals were grown on the N.R.C. furnace, two of which are production crystals included for comparison. From Table III it is seen that 6 out of the 7 crystals grown with the torus show a low vertical resistivity gradient, and an uncontrolled radial resistivity gradient. Obviously, optimum furnace conditions were not obtained. The low vertical gradient was unexpected and may have been partly due to the small crystal diameters. Future emphasis, however, will be placed on larger diameter and longer crystals for production.

Repairs to the floating crucible furnace were completed. A total of 6 crystals were grown. As shown in Table III five crystals (Nos. 11 through 15) were grown consecutively on this furnace with or without the graphite torus. The objective was to determine the yield, resistivity control and dislocation control capability of the floating crucible furnace. Dislocation control is discussed in Section 1.1.2. An 81% yield of single crystal was realized in the 20-10 ohm cm range based on net weight. The remaining 19% of crystal weight was 15% and 4% in the 23-20 and 10-8.4 ohm cm ranges, respectively. Each crystal was 13 to 14 inches long as shown in shadowgraphs in Fig. 1. An attempt was made to maintain crystal diameter 3/4 to 7/8" during the series. Generally, about 11 inches of each crystal was of desired resistivity. The variation of the vertical resistivity gradient was narrow and calculated to be less than 2% per linear inch (or about 1/2 ohm cm per linear inch). As a comparison production crystals made on the N.R.C. furnace usually show over 5% vertical gradient per linear inch and a yield of less than 40% in this resistivity range. Thus, a significant improvement in the vertical gradient was accomplished in fulfillment on one of the contracts' objectives.

For the next quarter, a study of other growth parameters will be made. In previous runs, the inner crucible contained a .093 inch capillary. The effect of a different diameter capillary will be investigated. The capillary controls the distribution of dopant in both crucibles. Ideally, no redistribution of dopant is desired via either diffusion or mass transfer phenomena. If the capillary is too large, molten germanium will flow in both directions and the resulting resistivity profile of the crystal will approach that of a crystal grown from a single crucible.

1.1.1 Resistivity Control (cont'd)

Also, in the next quarter, the effect of angular seed rotation and pull speed on the effective segregation coefficient will be investigated. The object is to enhance distribution of dopant at the solid-liquid interface in order to decrease the radial resistivity gradient. Thus, it is proposed to increase angular seed rotation and to decrease pull speed in order to maintain the $C > Co$ condition; where C = Concentration of dopant in the inner crucible and Co = Concentration of dopant in the outer crucible.

Conclusion:

Significant improvements in yield and the vertical resistivity gradient were demonstrated by use of the floating crucible furnace.

Program for Next Quarter

Grow a series of crystals to a specified resistivity range for a production run.

Investigate effect of capillary diameter in the floating crucible.

Investigate effect of angular seed rotation and pull seed.

1.1.1.1 Optimization of Resistivity & Etch Pit Ranges

Recommendations:

As explained in full detail in the body of this discussion, our findings in the resistivity - etch pit optimization experiment lead us to put forth the following recommendations:

In view of the newly proposed and tighter specifications on the 2N1430 type transistor, use:

1. Resistivity 10 - 20 ohm-cm.
2. Etch pit count 1000 - 2000 pits/cm^2.

Introduction:

Work performed during this quarter was devoted to optimizing the resistivity - etch pit combination for the 10 Amp DAP, 2N1430, type transistor. In order to obtain the maximum amount of information out of a given number of data points, as well as the most precise estimate of experimental error, the so-called Factorial Design was utilized. When the requisite con ditions have been met, this type of design will give information not only on the effects brought about by the individual input variables, but also it will point out first, second, and higher outer interactions, if any, among the variables.

1.1.1.1 Optimization of Resistivity & Etch Pit Ranges (cont'd)

To briefly show why the factorial design is more efficient, we shall present the following example: We wish to study the effects of changing the temperatures and the pressures in a given experiment. The classic way to do this is by the "one-factor-at-a-time" method, illustrated in Figure A. Here we get first a measurement at T_1P_1. We now change the temperature only to obtain a point at T_2P_1. Then we change the pressure only, and get a reading at T_1P_2. To estimate the effect of temperature we consider the difference (2) - (1), and to estimate the effect of the pressure, we look at the difference (3) - (1). Because of experimental error, we might wish to confirm our results by duplicating the same experiment. Thus, six (6) observations would be required to make two comparisons each on the temperature and pressure effects. Note also that we have no information whatsoever on possible interaction between the variables.

Suppose, now, that we were to add one more observation to the original 3 by completing the square; in other words, by obtaining one measurement after having changed both the temperature and the pressure. This is shown in Figure B as T_2P_2. To estimate the effect of temperature, we can now compare [(2) - (1)] and [(4) - (3)]. Similarly to estimate the effect of pressure, we can compare [(3) - (1)] and [(4) - (2)]. As can be seen, we were able to make two comparisons each on temperature and pressure effects with only four observations (as contrasted with six observations for the one-factor-at-a-time design). There is, in addition, a further benefit: whereas the "one-factor-at-a-time" gave us no clue as to possible interaction between the variables, the factorial experiment does bring this out most natusally by comparing [(1) + (4)] - [(2) + (3)].

	T_1	T_2
P_1	(1)	(2)
P_2	(3)	

Change one factor at a time.

Figure A

	T_1	T_2
P_1	(1)	(2)
P_2	(3)	(4)

Factorial Design

Figure B

III - RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (CONTINUED)

1.1.1.1 Optimization of Resistivity & Etch Pit Ranges (cont'd)

Summary:

I. a) The "one-factor-at-a-time" design uses only part of the observations to estimate an effect.
   b) The factorial design uses all of the observations to estimate each effect.

II. a) The "one-factor-at-a-time" design cannot reveal anything about interaction between the factors.
    b) The factorial design is eminently suited to point out interaction among the variables.

The Design:

For a factorial design in which some (or all) of the factors are quantitative in nature, it is possible, and indeed desirable, to analyze the data to see whether the various levels of the input variable constitute a linear, or a quadratic, or a cubic, etc., relationship. This can be most conveniently handled by the use of orthogonal polynomials*, since for this type of polynomials, the necessary constants have been precalculated and tabulated. However, one of the requirements for the use of this table is that the points at which the data is read be equally spaced. If this cannot be done conveniently, then one has the alternative of making the ratio of the consecutive points be constant and then analyze the logarithms since the logarithms of numbers having a constant ratio are equally spaced.

With these points in mind, a matrix was designed, and it is shown in Figure C. It can be observed that the resistivities are equally spaced, while it is the logarithms of the etch pits that are equally spaced.

In order to insure that only the correct resistivity - etch pit combination went into each cell of the matrix, the individual slices were checked for resistivity on the micro-wave set and the measurements were corroborated with the four-point probe making certain that the correction factors for thin slices were applied as required. Also, the dislocation etch-pits were counted on the individual slices. The wafers, then were categorized and identified with their corresponding cell in the matrix (such as 4A, 3C, etc.). Following this, they were subjected to the normal manufacturing process in accordance with current specifications governing the various operations. The units were then properly aged and electrical data was obtained on a Type 575 Curve Tracer.

* SEE O.L. Davies - "Design and Analysis of Industrial Experiments" Hafner Publishing Company, New York, 1956, Appendix 8C, Page 344 et seg.

1.1.1.1 Optimization of Resistivity & Etch Pit Ranges (cont'd)

A sufficient quantity of units was started to insure that at least 20 good units would be available for each cell of the matrix (required: 12 x 20 = 240 units).

Resistivity
P = ohm-cm

			1	2	3	4
			0 - 5	5 - 10	10 - 15	15 - 20
ETCH PIT ε	A	0 - 500				
	B	500 - 1000				
	C	1000 - 2000				

Matrix
Figure C

Analysis:

One of the underlying assumptions in an analysis of variance is that the variances of the different groups must be homogeneous (as established by an "F Test" or a "Bartlett Test")[1] In addition, it is always a good policy to look at the data pictorially to quickly judge whether any peculiarity can be spotted in the measurements. It is well known that the arithmetic average is an efficient estimator of the central tendency of the unddrlying population. Unfortunately, it is unduly influenced by extreme values. Furthermore, in order to obtain confidence limits, one must assume something about the shape of the population. The median, (the middle value of the ordered data), on the other hand, is a somewhat less efficient estimator. However, it has two important assets; namely, (1) it is relatively insensitive to extreme values, and (2) it is possible to make confidence statements about it with no assumption about the underlying distribution of the population, except that the observations are on a continuous variable[2]. For these reasons, we plotted the medians of these significant electrical parameters, along with 95% confidence limits. Figures D, E, and F show the following as far as can be judged from the confidence limits:

(1) SEE O.L. Davies

(2) SEE Dixon and Masey "Introduction to Statistical Analysis" McGraw Hill, Second Edition, 1957, Page 294.

III - RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (CONTINUED)

1.1.1.1 Optimization of Resistivity & Etch Pit Ranges (cont'd)

1. I_{CBO} - There appears to be homogeneity of the variances and therefor an analysis of variance would appear appropriate.

2. BV_{CER} - It is not possible to say, off-hand, whether homogeneity of variance exists and a Bartlett Test is indicated.

3. I_B - The variances are obviously non-homogeneous, and an analysis of variance would not be justified.

Results:

1. An analysis of variance was performed (attached) and it reveals no significant difference between the various levels of the variables as evidenced by the I_{CBO} @ 1.5 V.

2. A Bartlett Test (attached) shows the data on the BV_{CER} does not exhibit homogeneity of variance, and therefore, an analysis of variance is not justifiable.

Conclusion:

The newly proposed specification limits for the various parameters were drawn in on the graphs (Figure D,E, and F) and based on them , the following conclusions were drawn:

1. I_{CBO} All the groups meet the requirements.

2. I_B The following groups meet the requirements: 1B, 3B, 4B, 2C, 3C, and 4C

3. BV_{CER} The following groups meet the requirements: 2A, 3A, 3C, and 4C

The groups fitting all three requirements are therefore:
3C and 4C

One recommendation, therefore, is to consider groups 3C and 4C as the optimum etch pit - resistivity combinations. In terms of actual units this means:

$$\left.\begin{array}{l}10 - 15 \text{ ohm-cm} \\ 15 - 20 \text{ ohm-cm}\end{array}\right\} 1000 - 2000 \text{ etch pit/cm}^2$$

Status:

In view of the great variability encountered within the groups, it appears desirable to obtain a confirmation of our present results and at the same time to extend further our investigation: this time the low resistivities (less than 10 ohm-cm) and the low etch-pits (less than 1000 pits/cm^2) will be dropped in favor of new categories on the high side (resistivities larger than 20 ohm-cm and etch-pits larger than 2000/cm^2).

BARTLETT'S TEST (1.1.1.1)

This test will be applied to the BV_{CER} data.

Let us define the following terms:

$S^2 i$ = variance of the i'th category.

i = 1, 2, 3----k = number of categories, up to k

Mi = number of observations in the i'th category

$N = \sum_{i=1}^{k} ni$ = total number of readings

$$S^2 p = \frac{\sum_{i=1}^{k} (n_i - 1) S_i^2}{N - k}$$

M = (N-k) lu $S^2 p$ -

lu = logarithm to the base e = 2.72

$$A = 1/3(k-1) \left[\sum_{i=1}^{k} \left(\frac{1}{n_i - 1} \right) - \frac{1}{N-k} \right]$$

V_1 = k-1 = degrees of freedom of the numerator in the F-test.

V_2 = k+1/A^2 = degrees of freedom of the demominator in the F-test.

b = V_2/1-A+ (2/V_2)

Then we compare F = $V_2 M/V_1$ (b-M) to the value tabulated in an F-table.

Applying this to our BV_{CER} data, we find:

Category	$(Mi-1) S^2 i$	$S^2 i$	lu $S^2 i$
1A	7,048	793	6.66
1B	855	95	4.55
1C	8,455	938	6.83
2A	6,716	742	6.60
2B	14,240	1581	7.36
2C	9,428	1046	6.94
3A	17,890	1986	7.57
3B	11,272	1251	7.14
3C	13,944	1548	7.33
4A	3,259	361	5.89
4B	3,962	440	6.08
4C	34,932	3877	8.26

Bartlett's Test (1.1.1.1) (cont'd)

S^2p = 132,001/120-12 = 1,222 lu S^2p = 7.12

M = (120-12) 7.12 - 9 [81.21] = 768.96 - 730.89 = 38.07

A = 1/3(12-1) [12/10-1 - 1/120-12] = 1/33 [1.33 - .009] = .04

V_1 = 12-1 = 11

V_2 = $12+1/(.04)^2$ = 13/.0016 = 8,125

b = 8,125/ 1-.04 + 2/8,125 = 8,463

F = 8,125 (38.07)/ 11 (8,463 - 38.07) = 3.34

From an F-table, with degrees of freedom 11 and ∞, we find:

$F_{.95}$ = 1.79

$F_{.99}$ = 2.25

We may conclude that, at the 99% confidence level, the variances are not homogeneous.

ANALYSIS OF VARIANCE (1.1.1.1)

(Measurements are in milliamperes)

Etch Pit	Resistivity 1		2		3		4		Row Total
A	.03	.03	.03	.04	.04	.07	.04	.06	3.80
	.04	.11	.06	.03	.05	.05	.04	.05	
	.04	.17	.04	.04	.05	.04	.05	.08	
	.05	.04	.05	.05	.05	.07	.05	.05	
	.04	.05	.06	.05	.05	.04	.04	.06	
	.03	.03	.05	.05	.05	.04	.04	.06	
	.05	.02	.07	.06	.04	.05	.05	.05	
	.02	.04	.05	.04	.05	.04	.04	.06	
	.03	.04	.06	.02	.05	.04	.05	.03	
	.02	.03	.04	.03	.05	.03	.05	.07	
	Sub-total 0.91		0.92		0.95		1.02		
B	.03	.03	.06	.04	.05	.04	.04	.06	3.88
	.05	.02	.04	.04	.05	.20	.05	.06	
	.03	.11	.23	.05	.04	.05	.05	.06	
	.07	.02	.03	.11	.05	.05	.05	.05	
	.03	.04	.04	.04	.04	.05	.05	.05	
	.03	.03	.05	.04	.04	.04	.06	.06	
	.02	.02	.04	.03	.05	.05	.05	.05	
	.02	.02	.03	.03	.04	.04	.06	.04	
	.03	.03	.05	.03	.05	.04	.05	.05	
	.02	.02	.04	.06	.05	.05	.06	.06	
	Sub-total 0.67		1.08		1.07		1.06		
C	.05	.03	.03	.03	.09	.04	.04	.06	3.80
	.15	.03	.05	.04	.04	.05	.05	.07	
	.03	.06	.05	.04	.07	.05	.05	.05	
	.04	.03	.04	.04	.05	.04	.04	.05	
	.09	.04	.03	.04	.05	.04	.03	.06	
	.03	.03	.04	.04	.05	.04	.05	.05	
	.03	.02	.04	.08	.05	.05	.04	.05	
	.05	.25	.04	.03	.05	.04	.05	.04	
	.02	.02	.03	.03	.08	.04	.03	.04	
	.03	.03	.05	.04	.04	.04	.04	.04	
	Sub-total 1.06		0.81		1.00		0.93		
Column Totals	2.64		2.81		3.02		3.01		Grand Total 11.48

Each cell has 20 observations, and therefore, the total number of observations is 20 X 12 = 240. Let us now calculate the correction factor.

$$C.F. = (11.48)^2/240 = 131.79/240 = .549$$

$$\text{Sum of Squares, Total} = (.03)^2 + (.04)^2 + - - - - - - - - - + (.04)^2 + (.04)^2 - C.F.$$

$$= .724 - .549 = .175$$

Sum of Squares Between the 12 Means

$$+ = \frac{(.91)^2}{20} + \frac{(.92)^2}{20} + \cdots + \frac{(1.00)^2}{20} + \frac{(.93)^2}{20} - C.F. = .557 - .549 = .008$$

Sum of Squares for Rows

$$\frac{(3.80)^2}{80} + \frac{(3.88)^2}{80} + \frac{(3.80)^2}{80} - C.F. = .549 - .549 = .000$$

Sum of Squares for Columns

$$\frac{(2.64)^2}{60} + - - - \frac{(3.01)^2}{60} - C.F. = .551 - .549 = .002$$

A N O V A (Analysis of Variance)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	F. 95
Between Rows (Etch-Pit)	.000	2	.000	<1	3.00
Between Columns (Resistivity)	.002	3	.0006	<1	2.60
Interaction	.006	6	.001	1.4	2.10
Sub-total (Between the 12 Means)	.008	11	.0007	1.0	1.79
Within Observations (Error)	.167	228	.0007		
Total	.175	239			

From this analysis it appears that, at the 95% confidence level, there is no significant difference between the various categories.

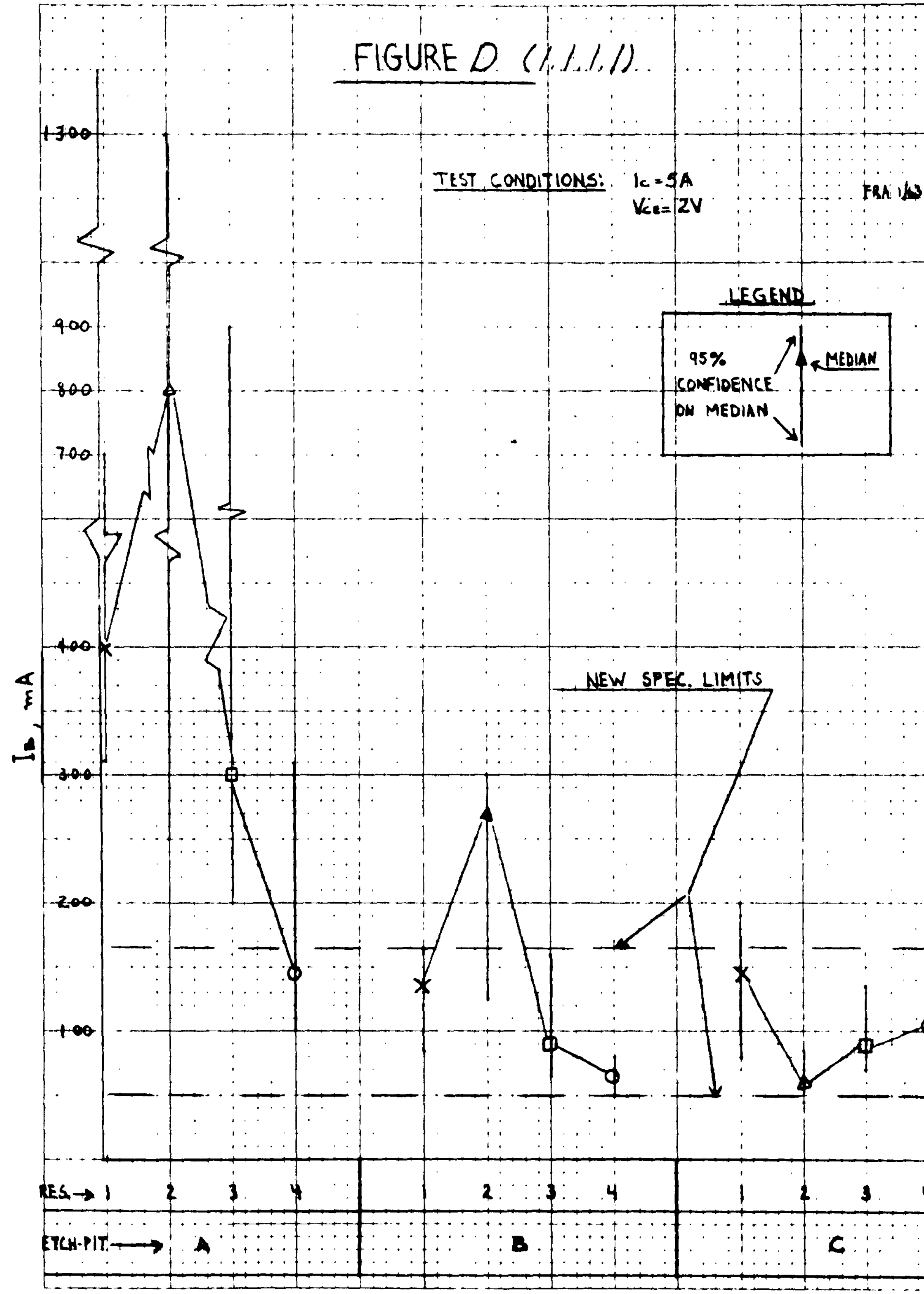
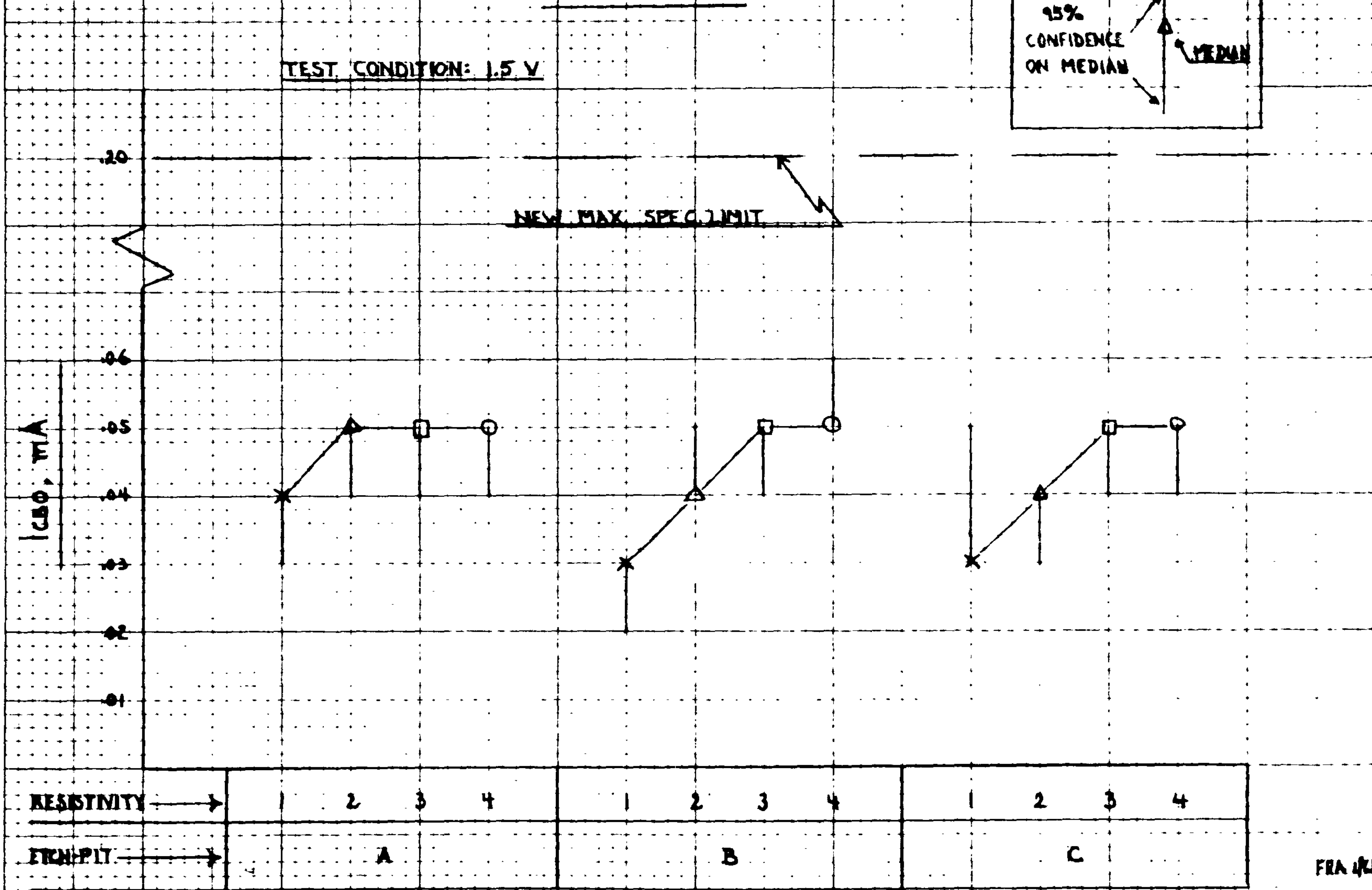


FIGURE D (1.1.1.1)
1300
900
800
700
400
300
200
100
I_B, mA
TEST CONDITIONS: I_C = 5A
V_{CE} = 2V
FRA 1/63
LEGEND
95% CONFIDENCE ON MEDIAN
MEDIAN
NEW SPEC. LIMITS
RES. → 1 2 3 4 1 2 3 4 1 2 3 4
ETCH-PIT → A B C

FIGURE E (1.1.1.1)



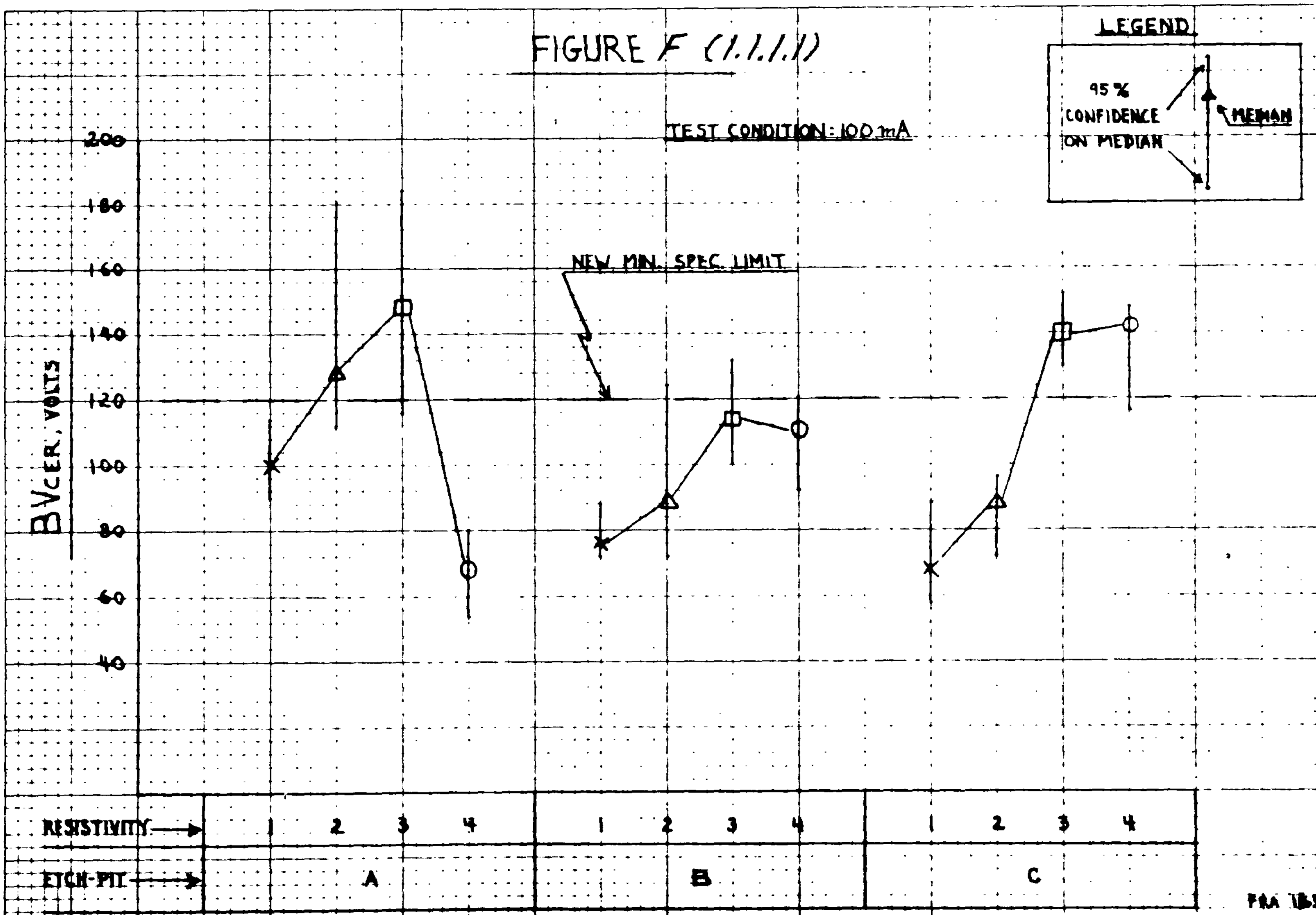


FIGURE F (1.1.1.1)
TEST CONDITION: 100 mA
LEGEND
95 % CONFIDENCE ON MEDIAN
MEDIAN
NEW MIN. SPEC. LIMIT
BVCER, VOLTS
200
180
160
140
120
100
80
60
40
RESISTIVITY
ETCH-PIT
1 2 3 4
A
B
C
FRA 1B3

1.1.2 Etch Pit Control - F. Arden & H. Sivik

The idea presented in the 2nd quarterly report relating torus hole size and crystal diameter with density of dislocation pits was evaluated.

It is seen from Table III that 7 out of 7 crystals grown on the N.R.C. furnace have a much lower dislocation density than the two production crystals grown without a torus. It is also seen that the dislocation density varies depending which torus was used. Essentially, it was demonstrated that the dislocation density of germanium crystals may be controlled by choice of a suitable torus.

Further, from Table III, five crystals (Nos. 11 through 15) grown on the floating crucible furnace show a similar result. For example, it was found that the dislocation count was reduced about 20%, 5% and 0% when using the $1\frac{1}{4}$', 1-3/4" and 2" diameter hole in the torus, respectively, below the dislocation count of crystals grown without the torus, while maintaining crystal diameter at 3/4 to 1" (See Fig. 1 shadowgraphs).

Another important observation is that crystals produced on the floating crucible furnace display at least a 50% higher dislocation density than crystals produced on the N.R.C. furnace. For example, crystal #6 displays a dislocation density at least three times greater than any crystal grown on the N.R.C. furnace when using the "E" torus. This condition is largely explained by the open design of that furnace thereby inducing high temperature losses. The result is greater thermal shock during crystal growth. Use of the torus is helpful in reducing dislocations below 2,000 per sq. cm.

For the next quarter, it is proposed to study the effect of a 1" diameter hole in the torus on the dislocation density in a 3/4" diameter crystal.

Conclusion:

The dislocation density of germanium crystals was shown to be controllable, at least partly, by means of a suitable torus in the dislocation density ranges from about 200 to 2,000 per sq.cm.

Program for Next Quarter:

A few crystals will be grown to a specified dislocation count for a production test run.

III - RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (CONTINUED)

1.1.3 Uniform Penetration in Diffusion - R. Colucci

During the quarter, work was continued on the use of a silicon dioxide mask on slices prior to diffusion. Difficulties have been encountered in consistently assuring that the masking is covering completely. Microscopic areas can be found where masking is incomplete. Only a small number of dice per slice are available because of the rather large die size, and therefore these areas of non-masking, even though microscopic and widely apart, cause considerable rejects in the finished element. Work is being continued to determine the best surface treatment and masking cycle to eliminate these areas of non-masking.

Conclusion:

Although the process appears to hold definite advantages in regard to cost and uniformity of electrical characteristics, it is felt that the process will not become an established production procedure during the time remaining in the contract. Bendix plans to continue this work beyond the present contract until a workable production process is arrived at or the process is definitely determined to be not feasible.

1.1.4 Depth Control in Alloying - Fred Arden

1.1.4.1 Introduction

Starting in November, 1962, acceptance for the thicknesses of the 10A dice after etching went on a control chart basis. The plan works as outlined below:

1.1.4.1.1 Form lots corresponding to the number of dice etched at one time (ordinarily 100).

1.1.4.1.2 Check, with micrometer, 10 dice out of a lot, compute the range and the average; plot on an $\bar{X}$ and R chart.

1.1.4.1.3 First look at the range:
(a) If it is larger than the specified limit, have Manufacturing inspect the lot 100% regardless of the value of the average.

(b) If it is inside the limits, act as in 1.1.4.1.4 below.

1.1.4.1.4 When the range is within specified limits, then:

(a) If the average is inside the control limits, accept the lot.

(b) If the average exceeds the upper limit, re-etch the lot.

(c) If the average is below the lower limit, inspect the lot 100%.

A typical chart showing how this method operates is attached (See Figure 2)

The control limits were obtained as shown in Appendix IV.

This report is then an evaluation of the effectiveness of the control chart technique as applied to the sampling plan as outlined above.

1.1.4.2 Some Results

Figure 3 shows the proportion of the cups accepted after etching, as the lots are submitted. It transpires that, on the average, 50% of the cups are accepted immediately, and an additional 30% are accepted after re-etch. The remaining 20% must be submitted to 100% inspection by Manufacturing on account of their being too widely distributed or being possibly undersized. Such inspection yields ordinarily 75% acceptable dice. All told, then, on the average we are accepting 80% on a sampling basis plus 15% after the 100% inspection, or a total of 95% of each lot submitted.

Figure 4 indicates the variability of the process as we can deduce it from the ranges. We may observe a dramatic change for the better in the variability of the process. This may be attributed to a learning pierod during which the operators acquire a "feel" for how to obtain proper results.

III - RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (CONTINUED)

1.1.4.3. About The Sampling Plan

It now becomes of interest to obtain answers to some questions about the sampling plan that was outlined above, namely:

1.1.4.3.1 What is the worst average quality of the dice going to alloying (Average Out-going Quality Limit= AOQL)?

1.1.4.3.2 How many dice are inspected on the average?

1.1.4.3.3. Which quality will be rejected 90% of the time? (This is known as the consumer's protection, and also as Lot Tolerance Percent Defective = LTPD)

1.1.4.4 The answers to these questions are arrived at in Appendix V, and are summarized here for convenience:

1. The average quality going to alloying is no worse than AOQL=6% defective.

2. Average number of dice inspected per cup = 30 (This includes all the cups inspected 100%).

3. 22% or worse defective has 90% or better chance of rejection.

1.1.4.5 Status

It is contemplated at this time to make certain changes in the etching operation that will make it possible to improve the yields by reducing the variability of the process. For example, a reduction of the average-range from .31 (at present) to .26 (possible) would obtain the following:

1. AOQL From 6% (now) to 4%.

2. Average number of dice inspected from 30 (now) to 14.

3. 90% or better chance of rejecting a lot 15%, or worse, defective (instead of 22% defective as at present).

It will thus be possible to further improve the overall quality of the work.

III. RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (CONTINUED)

1.1.5 Spreading and Wetting in Alloying

As the depth control and alloying is also affected, it will be necessary in all cases to consider spreading and wetting in alloying in conjunction with "1.1.4 Alloy Depth Control in Alloying" since depth penetration in surface spreading are closely dependent on one another.

III - RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (CONTINUED)

1.1.6 Collector Attachment - Ray Colucci

A large quantity of boss-less platforms were processed. The thermal results of this larger run did not substantiate initial data, but showed a thermal resistance comparable to the standard package with no improvement justifying a package redesign.

(See data table IV).

Conclusion:

It can be concluded at this time that the collector attachment has been finalized to the use of the ultrasonic mounting technique as outlined in the first quarterly report.

III - RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (CONTINUED)

1.1.7 Surface Passivation and Final Preparation Prior to Sealing

The present production techniques have been finalized.

(See Quarterly Report No. 1)

1.1.8 Gettering Techniques - Ray Colucci

The final experiments regarding the optimum gettering material have been completed. It has been concluded that the best gettering material from the point of view of unit stability over long, high temperature storage life conditions is molecular sieve in the pellet form.

As mentioned in the second quarterly report, a zinc compound was evaluated. Results after 1000 hours storage at 110°C show the zinc compound to be inferior to the molecular sieve pellet. (See Table V).

The production gettering technique has been now finalized to the use of an activated molecular sieve pellet.

1.1.9 Leak Determination - E. Yurowski

In Quarterly Report No. 2, a method of helium detection was described by use of a helium backfilling technique, which is based on a procedure of injecting helium into domed transistors, then measuring the rate of helium leakage from the transistor by means of the mass spectrometer method.

The tests presented herein were designed to evaluate several variables, such as optimum helium backfilling time and pressure, degree of repeatability, effective range of the mass spectrometer and if possible, the minimum meaningful leak rate which could be established as a specification limit.

Three hundred twenty (320) electrically "good" 10 Amp DAP transistors were selected for this evaluation. The devices were standard product, with the exception that no helium tests were performed during fabrication. The sample transistors were divided into a matrix of 16 groups of 20 devices each and tested in accordance with the conditions shown in Table VI . The various helium backfilling pressures selected for this study were chosen to provide a substantial spread and to cover the range of pressures now specified by various transistor manufacturers and users. Backfilling times of 1 hour, 3 hours, 6 hours and 16 hours were chosen for practical purposes, namely, that two 3-hour tests or one 6-hour test could be performed during one 8-hour shift period. The 16-hour test can be performed overnight. Approximately 1 hour is required for pretest conditioning and final post testing.

Data was recorded on a variables basis (individual readings for each device) and averages for each sample group are as shown in Table VII . Data from devices with observed leak rates of greater than 1.0×10^{-8} std cc He/sec were excluded from averages for this portion of the test.

Further analysis by attributes, still utilizing a limit of 1.0×10^{-8} std cc He/sec is shown in Table VIII. An Analysis of Means* applicable to attributes data is shown in Figure 8 .

*Reference Technical Report No. 2, February 10, 1960, prepared by Ellis R. Ott and Sidney S. Lewis, Rutgers University, New Brunswick, N. J. for Army, Navy and Air Force under Contract Nonr 404 (11), (Task NR-42-021) with the Office of Naval Research.

Examination of Table VIII and Figure II shows that a significantly* higher number of "failures" occurs at the 3-hour time period. Of particular interest, however, is the lack of influence due to backfilling pressure. An explanation of the lack of significance of the backfilling pressure is offered as follows: The pressure required to inject helium must be high enough to counteract the partial pressure within the dome of the transistor as the result of previous evacuation. However, injection of helium under any of the pressures utilized in this study was sufficiently high and little noticeable difference was recorded.

All mass spectrometer tests were conducted immediately after (within 30 minutes) the backfilling operation. If, however, a longer period was allowed to elapse between backfilling and leak detection, entirely different results would probably have been obtained, since the amount of injected helium would vary with the backfilling pressure and in turn, would escape from the dome of the transistor in a time period related to the backfilling pressure.

In testing for the minumum repeatable leak rate, 37 devices out of the original sample of 320 exhibited leak rates of 5.0×10^{-9} std cc He/sec or greater. The balance of the sample indicated leak rates in the order of 10^{-10} std cc He/sec. Figure 9 illustrates the Trial 1 and Trial 2 test data. It should be noted that the 24 devices which read in the order of 10^{-9} std cc He/sec repeated for all units except one unit (No. 28 read 10^{-8} std cc He/sec) on the second trial run.

Of the 5 units which originally read in the order of 10^{-8} std cc He/sec, 2 repeated, 2 decreased to 10^{-9} and one increased to 10^{-7}.

Of the 5 devices which originally read 10^{-7} std cc He/sec, 3 repeated and 2 decreased to 10^{-8}.

Of the 3 devices which read 10^{-6} std cc He/sec, one repeated, one decreased to 10^{-7} and one decreased to 10^{-9}. The 10^{-6} leak readings should not be considered pertinent to the effectiveness of the Helium Leak Detection procedure, since the magnitude of leakage is within the effective range of the Detergent Bomb Hermetic Seal test and would normally be rejected.

*based on a 95% confidence level

CONCLUSIONS:

1. Backfilling pressure is not critical, provided that mass spectrometer measurements are taken immediately after (within 30 minutes) helium backfilling.

2. The optimum backfilling time appears to be in the area of 3 to 6 hours, which indicates that the presently accepted industry criteria of 4 hours is correct.

3. The minimum repeatable leak appears to be in the order of 1.0×10^{-9} std cc He/sec. However, leak rates of 10^{-8} and 10^{-7} can be expected to repeat within a range of one order of magnitude. (For example, a 10^{-8} leak can be expected to repeat as a 10^{-9} or 10^{-7} leak, but not as a 10^{-10} or 10^{-6} leak). In order to assure a given minimum leakage rate, specifications should be written to reflect a tightening of one order of magnitude.

4. Leak rates of 10^{-10} and 10^{-9} std cc He/sec are most probably not actual leakers, but rather "apparent" leakers, due to background noise, caused by the adherence of helium molecules on the surface of the device under test.

5. The maximum meaningful specification limit should not exceed 1.0×10^{-9} std cc He/sec.

TABLE I
2N1430
TEST SPECIFICATIONS

LINE	TESTS	% AQL	SYMBOL	LIMITS MIN.	LIMITS MAX.	LIMITS UNIT	NOTES	V_{CB} Vdc	V_{CE} Vdc	I_E Adc	I_B Adc	R_{BE} OHMS	V_{CC} Vdc	T °C	V_{EBO} Vdc	f kc
1	Collector Cutoff Current	1.0	I_{CBO}		-300	µAdc		-1.5						25		
2	Collector Cutoff Current	1.0	I_{CBO}		-50	mAdc		-100						25		
3	Emitter Cutoff Current	1.0	I_{EBO}		-50	mAdc								25	-1.5	
4	Collector Current	1.0	I_{CEO}		-100	mAdc			-40			∞		25		
5	Collector Current	1.0	I_{CER}		-50	mAdc			-80			100		25		
6	Base Current	1.0	I_B	-50	-165	mAdc			-2.0	5.0				25		
7	Base Current	1.0	I_B		-500	mAdc			-2.0	10				25		
8	Base Voltage	1.0	V_{BE}		-0.9	Vdc			-2.0	10				25		
9	Collector Saturation Volt.	1.0	$V_{CE(S)}$		-0.75	Vdc				10	-1.0			25		
10	Current Gain	4.0	h_{fe}	7.5					-6.0	50				25		100
11	Rise Time	4.0	t_r		5	µsec				5.0			-28	25		
12	Fall Time	4.0	t_f		2	µsec				5.0			-28	25		
13	Thermal Resistance	4.0	θ_r		1.5	°C/W	1									
14	Base Current	4.0	I_B	-50	-165	mAdc			-1.5	5.0				80		
15	Life Test (storage)						2									

MIL. SCL-7002/25A

RATINGS ABS. MAX. (at 25 °C)

SYMBOL	MAX.	UNIT
V_{CB}	-100	Vdc
V_{CE}	-40	Vdc
V_{EB}	-1.5	Vdc
I_C	-10.0	Adc
P_C	50	W
T_j	+100	°C
T storage	+100	°C

NOTES:

1. Junction to mounting base.
2. 1000 hours at 100° C.

Life Test 1000 hrs. End Points

SYMBOL	COND	MAX.	UNIT
I_{EBO}	Line 3	-75	mAdc
I_{CBO}	Line 2	-75	mAdc
I_B	Line 7	-625	mAdc

THE BENDIX CORPORATION

REV.	CHANGE No.	APPROV.	DATE	CHANGE

TABLE II
2N 1430 PROPOSED
TEST SPECIFICATIONS

DESCRIPTION:	CATEGORY:
	— TYPE —
APPLICATION:	EIA:
	BENDIX:
CLASS:	CUSTOMER:
DATA SOURCE:	CUSTOMER NAME:
WRITER:	CUSTOMER SPEC:

LINE	TESTS	%AQL	SYMBOL	LIMITS MIN.		MAX.	UNIT	NOTES	TEST CONDITIONS VCB Vdc	VCE Vdc	IC Adc	IB mAdc	RBE OHMS	T °C
1	Collector Cutoff Current	1.0	I_{CBO}			-200	µAdc		-2					
2	Collector Cutoff Current	1.0	I_{CBO}			-5	mAdc		-120					
3	Collector Cutoff Current	1.0	I_{CBO}			-10	mAdc		-100					85
4	Collector Cutoff Current	1.0	I_{CES}			-10	mAdc			-120			0	
5	Base Current	1.0	I_B			500	mAdc			-2	-10			
6	Base Current	1.0	I_B	56		167	mAdc			-2	-5			
7	Collector Saturation Volt.	1.0	$V_{CE(S)}$			-0.4	Vdc				-10	-1000		
8	Saturation Voltage	1.0	$V_{BE(S)}$			-0.9	Vdc				-10	-1000		
9	Collector-Emitter Brkdwn V.	1.0	V_{CEO}	-100			Vdc	1			-0.10		∞	
10	Collector-Emitter Brkdwn V.	1.0	V_{CEO}	-100			Vdc	2			-2.0			
11	Emitter to Base Brkdwn V.	1.0	V_{EBO}	-1.5			Vdc					50		
12	Rise Time	4.0	t_r			7	µs	3						
13	Fall Time	4.0	t_f			5	µs	3						
14	Storage Time	4.0	t_s			3	µs	3						
15	Life Test (Storage)	4.0						4						

RATINGS ABS. MAX. (at 25 °C)

SYMBOL	MIN.	MAX.	UNIT
V_{CB}		-120	Vdc
V_{CEO}		-100	Vdc
I_C		-10	Adc
P_C		30	W
T_j		110	°C
T_{stg}	-65	110	°C
I_B		±1.5	Adc

MIL. SCL-7002/25A

NOTES:

1. Full wave curve tracer
2. See Page 3 A
3. See Page 3 B
4. 1000 hours at 110° C.
5. Mechanical and environmental requirements of SCL-7002/25A must be met.

Life Test 1000 hrs. End Points

SYMBOL	COND.	MIN.	MAX.	UNIT
I_{CBO}	Line 2		-7.5	mAdc
I_B	Line 5		-625	mAdc
I_{EBO}	Line 11		75	mAdc

SUPERSEDES

OUTLINE DWG.

BRANDING DWG.

TIAL ISSUE - DATE:

R	CHANGE No.	APPRVD.	DATE	CHANGE

THE BENDIX CORPORATION

TABLE II
2N 1430 PROPOSED
TEST SPECIFICATIONS

DESCRIPTION:	CATEGORY:
	— TYPE —
APPLICATION	EIA
	BENDIX
CLASS	CUSTOMER:
DATA SOURCE:	CUSTOMER NAME
WRITER:	CUSTOMER SPEC

		LIMITS							TEST CONDITIONS					
LINE	TESTS	%AQL	SYMBOL	MIN	MAX.	UNIT	NOTES	V_{CB} Vdc	V_{CE} Vdc	I_C Adc	I_B mAdc	R_{BE} OHMS	T °C
1	Thermal Resistance	4.0	Θ_{J-C}		1.2	°C/W							
2	Switching Test	4.0					6			-10			
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													

RATINGS ABS. MAX. (at °C)

SYMBOL	MIN.	MAX.	UNIT

MIL. SCL-7002/25A

NOTES:

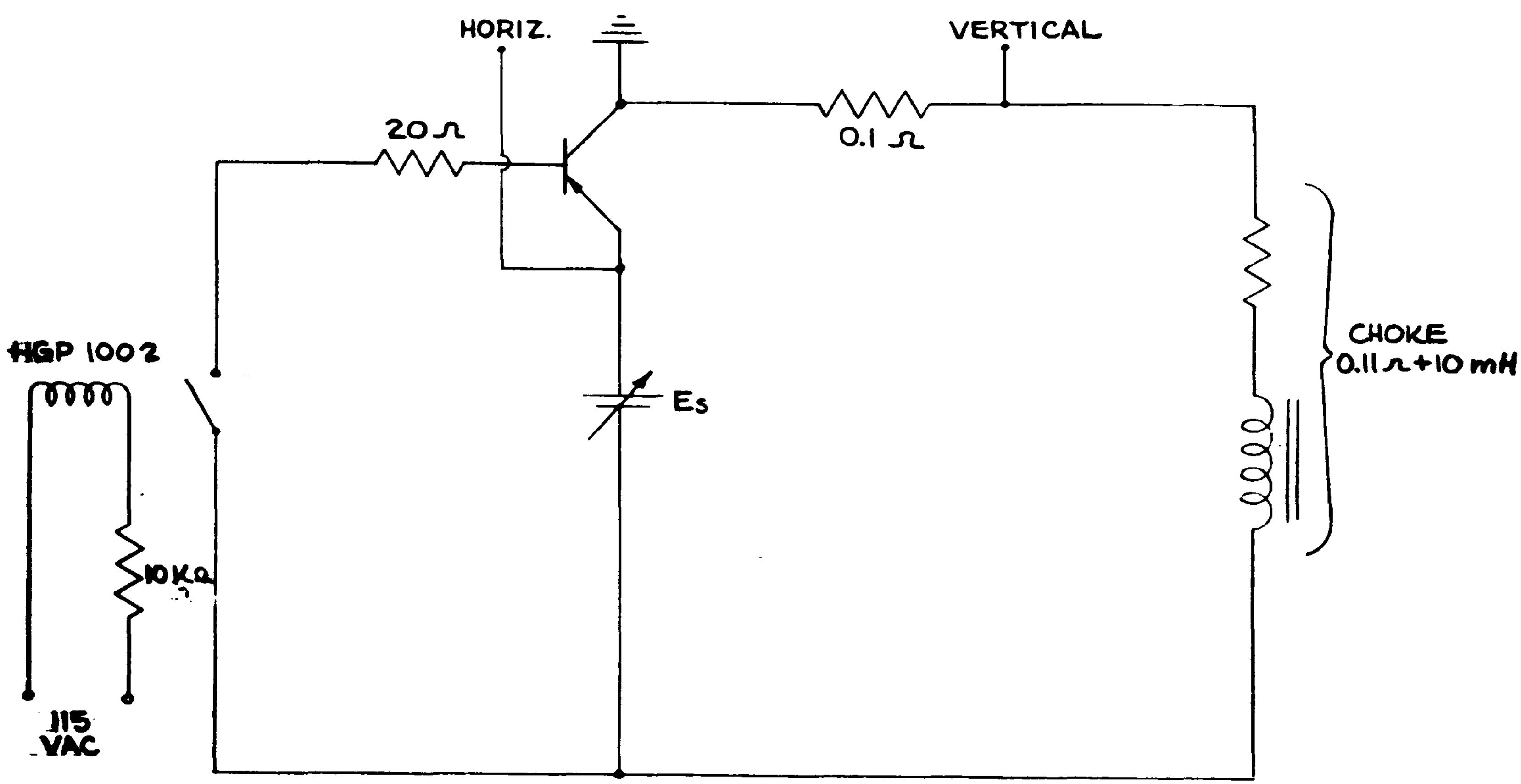
6. See Page 3C

Life Test hrs. End Points

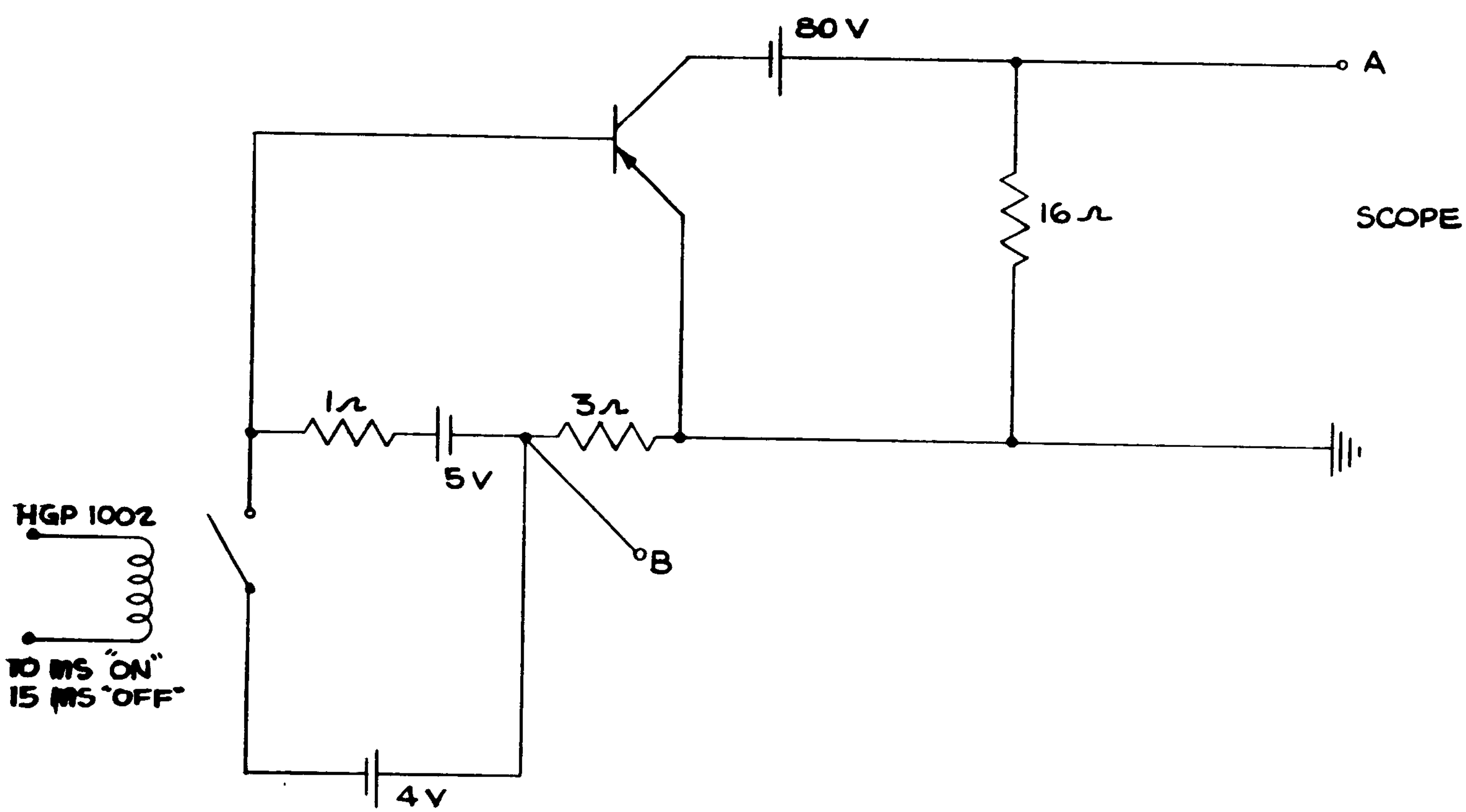
SYMBOL	COND	MIN	MAX	UNIT

SUPERSEDES | OUTLINE DWG | BRANDING DWG

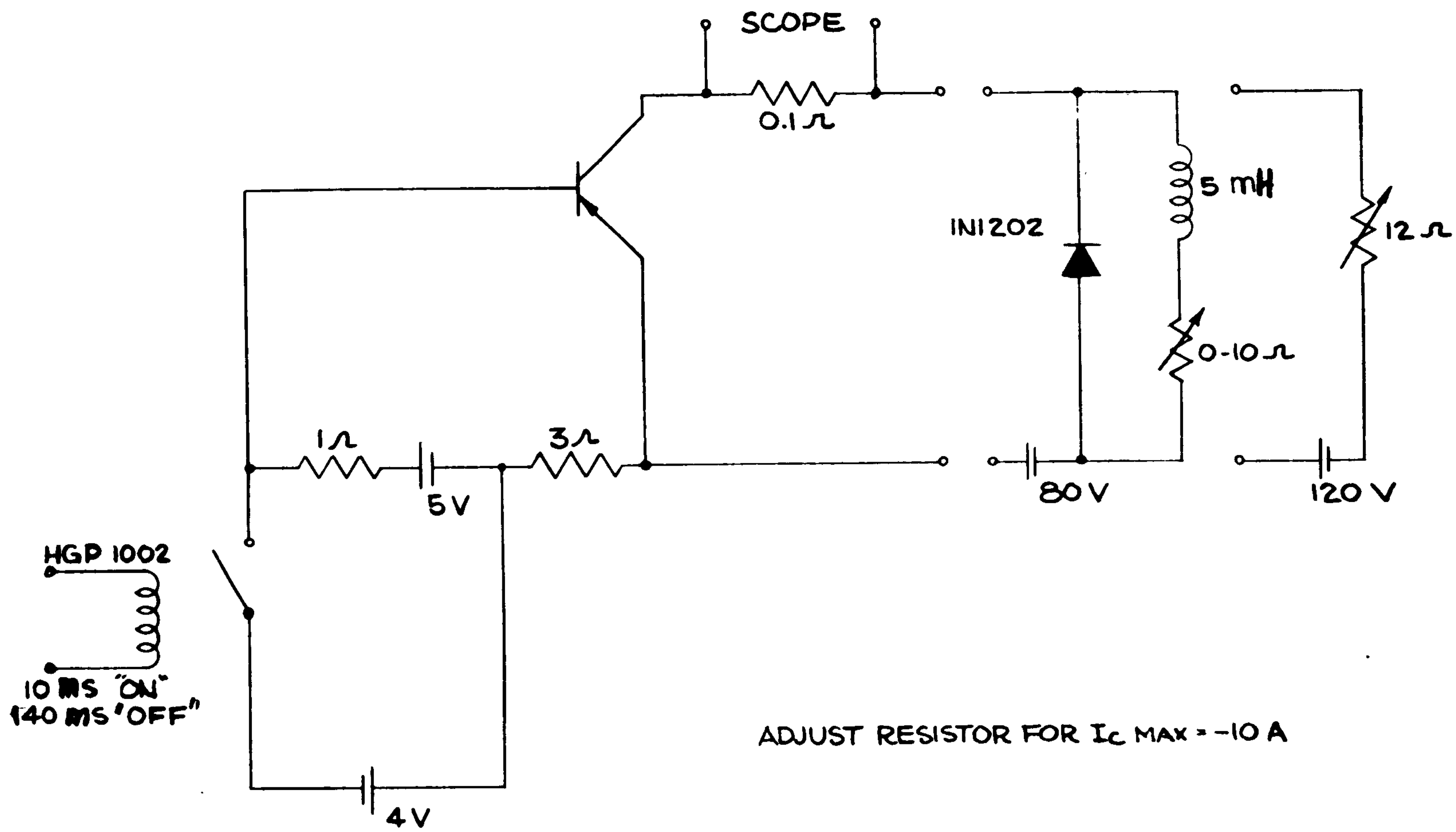
INDUCTIVE SWEEP TEST



RISE, FALL, STORAGE TIME



LOAD LINE SWITCHING TEST



ADJUST RESISTOR FOR I_c MAX = −10 A

III - RELIABILITY IMPROVEMENT PROGRAM NARRATIVE (CONTINUED)

TABLE III

DATA ON CRYSTALS PULLED IN 3RD QUARTER PERIOD

CRYSTAL NO.	IDENTI-FICATION	TYPE FURNACE	RESISTIVITY, OHM CM TOP READING	RESISTIVITY, OHM CM BOTTOM READING	$\Delta\rho$ GRADIENT RADIAL	$\Delta\rho$ GRADIENT VERTICAL INCH	TORUS NO.	DISLOCATIONS PER SQ. CM	CRYSTAL LENGTH IN.	CRYSTAL DIAM. IN.	REMARKS
1	Eng. 3	NRC	13-12	7.0-6.5	4.0	6.0	UNK.	160 - 200	5	1/2	
2	Spec.#1	NRC	14-13	13.5-12.0	3.6	0.6	C	300-900	5-3/4	11/16	
3	39HP	NRC	11.5-9.5	6.8-6.2	9.5	4.0	None	3,000-5,000	6	15/16	Prod. Crystal, selected for high etch pit run.
4	Spec.7	NRC	19-12.2	10.2-8.5	20.5	4.4	F	100-700	5½	3/4-5/8	
5	Spec.9	NRC	29.5-25	28-25	10	0.6	E	200	3½	5/8	
6	Eng.14	NRC	6.0-5.5	5.8-5.9	4.4	0.52	F	740-940	6	5/8-3/4	
7	Eng.15	NRC	9.0-8.2	8.0-7.0	4.6	2.3	F	420-640	3	9/16	
8	Eng.6	NRC	5.0-4.8	5.0-4.2	2.0	0.64	E	200-500	5	5/8	
9	A37DF	NRC	28-23	14-13.8	9.7	6.0	None	2,000-3,000	5	1-7/8	
10	Spec.2	Fl.Cruc.	6.0-5.0	5.8-4.5	9.1	0.61	E	1,500-1,800	4½	9/16	Note much higher etch pit count
11	Spec. 20	Fl.cruc.	23-19.9	19.2-15.9	7.2	1.4	None	2,750-1,700	12	3/4-5/8	
12	Spec.21	Fl.Cruc.	21-16	14-13	13.5	1.4	None	2,440-1,800	11	1-1/8-9/16	
13	Spec.22	Fl.Cruc.	20-15	13.5-11	14	1.4	E	1,580-1,540	11	7/8	1¼" Torus
14	Spec.23	Fl.Cruc.	18-15	13-11.2	9.1	0.7	G	2,780-1,640	11	3/4-5/8	2" Torus
15	Spec.24	Fl.Cruc.	19-14	12-8.4	15.2	1.9	F	2,020-2,060	11½	1-7/8	1-3/4" Torus

TABLE IV

COLLECTOR ATTACHMENT (1.1.6)

Θ_R V_{CE} = -10 V	
A	B
°C/W	°C/W
1.33	1.45
1.05	.80
.65	.67
1.26	1.32
1.01	1.31
.82	.96
1.39	.98
.95	1.08
.90	.79
.75	.97
1.15	1.04
1.12	1.21
.86	.54
.54	.95
.99	.73
.70	.42
.73	.75
.75	.63
.73	.73

Group A $\bar{X}$ = 1.2 σ = .186

Group B $\bar{X}$ = 1.2 σ = .225

Group A = Bossless Platforms

Group B = Standard Production

TABLE V

DESICCANT EVALUATION (1.1.8)

	ICBO VCB = 1.5V		ICER VCE = 80V RBE = 100Ω		IB VCE = 2V, IC = 10A	
	A	B	A	B	A	B
UNIT NO.	μa	μa	ma	ma	ma	ma
1	78	45	0.2	*1.0	350	350
2	52	42	0.1	.12	330	200
3	48	—	.09	—	350	—
4	47	37	0.2	0.1	370	300
5	43	40	0.1	0.5	240	300
6	51	—	.09	—	380	—
7	40	38	0.7	0.3	300	250
8	43	50	.08	*100	175	380
9	54	40	.12	*0.3	230	300
10	42	57	3.5	0.1	200	300
11	52	60	0.1	*50.0	250	220
12	55	57	1.4	0.1	350	200
13	49	—	.12	—	260	—
14	48	37	0.9	1.4	350	220
15	67	58	.38	*0.6	220	300
16	40	42	.12	*.15	400	250
17	50	48	.12	*0.8	300	250
18	39	63	.05	3.0	200	270
19	38	44	.05	.15	400	325
20	48	48	0.6	.15	200	310
21	63	160	0.6	*3.0	210	250
22	40	37	.12	10.0	350	310
23	51	52	.20	*0.2	300	350
24	42	50	.09	*0.2	350	325
25	70	61	.25	.25	310	250

GROUP A = MOLECULAR SIEVE PELLET

GROUP B = ZINC OXIDE PELLET

* Hysterisis loop

— Catastrophic failure

TABLE VI

LEAK DETERMINATION TEST MATRIX

20 TRANSISTORS PER TEST

25 PSI 1 HR.	25 PSI 3 HRS.	25 PSI 6 HRS.	25 PSI 16 HRS.
50 PSI 1 HR.	50 PSI 3 HRS.	50 PSI 6 HRS.	50 PSI 16 HRS.
75 PSI 1 HR.	75 PSI 3 HRS.	75 PSI 6 HRS.	75 PSI 16 HRS.
100 PSI 1 HR.	100 PSI 3 HRS.	100 PSI 6 HRS.	100 PSI 16 HRS.

HELIUM BACKFILLING PRESSURE & TIME

TABLE VII

TIME (HOURS)

	1	3	6	16	PRESSURE (PSI)
	9.37	4.90	4.14	6.76	25
	7.24	7.68	6.10	5.93	50
	6.64	5.38	7.30	8.20	75
	8.40	7.07	6.10	6.75	100

AVERAGE LEAK RATE ($x10^{-10}$ cc/sec.)
(Excluding Leaks $> 1.0x10^{-8}$ cc/sec.)

TABLE VIII

PRESSURE (PSI)	TIME (HOURS) 1	3	6	16	TOTALS
25	0/20	2/20	1/20	1/20	4/80
50	0/20	3/20	1/20	1/20	5/80
75	0/20	2/20	0/20	1/20	3/80
100	1/20	1/20	3/20	0/20	5/80
TOTALS	1/80	8/80	5/80	3/80	17/320

ATTRIBUTE "FAILURES"

(Devices indicating Leak Rates greater than 1.0×10^{-8} cc/sec)

(PROPOSED)
MILITARY SPECIFICATION
TRANSISTOR, PNP, GERMANIUM
TYPE 2N1430

1. SCOPE

1.1 Scope. This specification covers the detail requirements for a Germanium Diffused Alloy PNP switching transistor with the following characteristics at $T_J = 25^\circ$ C.

SYMBOL	h_{FE}	V_{CE} (Sat.)	V_{BE} (Sat.)	t_r	t_s	t_f
CONDITIONS	IC=10A,Vce=-2V	IC=-10A,Ib=-1A	IC=-10A,IB=-1A	IC=-5A		VCC=80V
UNIT	-	V	V	µs	µs	µs
MIN.	20	- - -	- - -	- -	- -	- -
MAX.	60	-0.4	-0.9	7.0	3.0	5.0

1.2 ABSOLUTE MAXIMUM RATINGS

SYMBOL	P_T (Average) (1)	P_T (Peak) (2)	T_{STG}	T_J	BV_{CBO}	BV_{CEO}	I_C	I_B
UNIT	W	W	°C	°C	V	V	A	A
MAX.	70	800	-65 to +110	110	-120	-100	-10	±1.5

NOTES:

1. For steady state conditions with forward bias and switching applications

$P_T = \left|I_C V_{CB}\right| + \left|I_E V_{EB}\right|$ derate 1.2°C/W for case temperatures > 25°C.

2. Peak power in switching applications

2.0 APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on invitation to bids form a part of this specification:

Specifications:

Military:
MIL-S-19500 Transistors, General Specification for

Standards:
MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes and Appendix, Sampling for Expensive Testing by Attributes

MIL-STD-202 Test Methods for Electronics and Electrical Component Parts

MIL-STD-750 Test Methods for Semiconductor Devices

3. REQUIREMENTS

3.1 Requirements: Requirements shall be in accordance with Specification MIL-S-19500, and as specified herein.

3.2 Abbreviations and symbols. The abbreviations and symbols used herein are defined in Specification MIL-S-19500 and as follows:

hFE	Static Forward Current, Transfer Ratio
VCE(sat)	Collector Saturation Voltage
Θ_{J-C}	Thermal Resistance, Junction to Case
ICEO	Collector to Emitter Cutoff Current, Base Open
ICBO	Collector Cutoff Current
IEBO	Emitter Cutoff Current
ICER	Collector to Emitter Cutoff Current, Resistance return from base to emitter
ICES	Collector Cutoff Current, Base Shorted
t_r	Pulse Rise Time
t_f	Pulse Fall Time
t_s	Storage Time

3.3 Design and Construction. Transistors shall be of the design, construction and physical dimensions specified on Figure 1.

3.4 Lead Arrangement. The lead arrangement shall be as indicated on Figure 1.

3.5 Operating Position. Transistors shall operate in any position.

3.6 Performance Characteristics. Performance characteristics shall be as specified in Tables I, II.

3.7 Marking. In addition to the marking specified in Specification MIL-S-19500 transistors shall be marked with the appropriate type designations and U. S. Army prefix after qualification has been obtained, and with the qualification code and manufacturer's identification.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Sampling and Inspection. Sampling and inspection shall be in accordance with specification MIL-S-19500 and as specified herein.

4.2 Qualification Inspection. Qualification inspection shall consist of the examinations and tests specified in Tables I and II.

4.3 Inspection Conditions. Inspection shall consist of the examinations and tests specified in Tables I and II.

4.4 Group A Inspection. Group A inspection shall consist of the examinations and tests specified in Table I.

4.5 Group B Inspection. Group B inspection shall consist of the examinations and tests specified in Table II.

4.6 Disposition of sample units. Sample units which have been subjected to and have passed Group B inspection may be delivered on the contract or order, provided that, after Group B inspection is terminated, these sample units are subjected to and pass Group A inspection.

4.6.1 LIFE TESTS. Life tests shall be performed on sample units which have been subjected to and have passed Group A inspection.

4.6.2 1000 Hours Life Tests.

(a) 1000 hours life tests shall be in effect initially and shall continue in effect until the eligibility criteria for reduced hours life test have been met.

(b) The measurements listed under end points in Table II shall be made at 0 hours, 340 + 72 - 24 hours, 670 + 72 - 24 hours, and 1000 + 72 -24 hours. Additional readings may be taken at the discretion of the manufacturer.

(c) Sample units shall meet the criteria specified in Table II.

If a life test sample fails either the 340 or 670 hour acceptance criteria for storage life or operation life, the lot shall be rejected. The tests may be terminated at the discretion of the manufacturer. However, the results of either of these tests shall not be used at a future date for acceptance of the same lot.

4.6.3 Reduced hours life tests. (670 or 340 hours) To qualify for reduced hours life tests, the following criteria shall be met:

(a) The immediately preceding 5 lots have been accepted.

(b) The average per cent defective over the preceding five lots at full test time has not exceeded 0.2 of λ.

(c) There has been no unusual discontinuity in production in the immediately preceding 5 lots.

4.6.4 After establishing eligibility, production lots shall be released for shipment at 670 hours or 340 hours, provided the life test sample has not exhibited more than the allowable number of failures.

4.6.5 The manufacturer shall establish eligibility for 670 hours first, thence he shall meet the criteria of a, b and c of 4.6.3 at 670-hour release to qualify for 340-hour release. Lots which are accepted under early shipment may be shipped. However, the life test shall continue through the full 1000 hours. The manufacturer shall lose eligibility for 670-hour or 340-hour release whenever two of five consecutive lots have failed the life test or the percentage defective over the preceding five lots exceeds 0.4 of λ at full time. Loss of eligibility for 670-hour release shall result in institution of 1000 hour release. Loss of eligibility for 340-hour release shall result in institution of 670-hour release.

4.6.6 Resubmitted lots. Lots, from which defectives have been screened out or reworked and which are resubmitted for acceptance inspection, shall contain only devices which were in the original lot. Resubmitted lots shall be kept separate from new lots and shall be clearly identified as resubmitted lots. Resubmitted lots shall be inspected for all characteristics, using tightened inspection, only for the characteristics failed. Lots may be resubmitted a maximum of two times. At the discretion of the Government, testing of characteristics which are not affected by the screening process may be omitted for resubmitted lots.

4.7 Rise and fall time. Rise and fall time measurements shall be made using the circuit of Figure .

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery shall be in accordance with Specification MIL-S-19500.

6. NOTES

6.1 Notes. In addition to the notes specified herein, the notes specified in Specification MIL-S-19500 are applicable to this specification.

TABLE I. GROUP A INSPECTION

EXAMINATION OR TEST	CONDITIONS [1*]	LTPD	MINIMUM REJECTION NUMBER	SYMBOL	LIMITS MIN.	LIMITS MAX.	UNITS
SUBGROUP 1		10	5				
Visual & Mechanical Examination	Method 2071			- - -	- - -	- - -	- - -
SUBGROUP 2		5	4				
Collector to Base Cutoff Current	Method 3036 VCB=-2Vdc IE = 0			ICBO	- - -	-0.20	mAdc
Collector to Base Cutoff Current	Method 3036 VCB =-120Vdc			ICBO	- - -	-5.0	mAdc
Collector to Emitter Cutoff Current	Method 3041 VCE =-120Vdc RBE = 0			ICES	- - -	-10.0	mAdc
Breakdown Voltage Emitter to Base	Method 3026 Cond. D IE =-50mA			BVEBO	-1.5	- - -	Vdc
Breakdown Voltage Collector to Emitter	IC =-100mA 120 cycle Repetitive Sweep			BVCEO	-100	- - -	Vdc
SUBGROUP 3		5	4				
Forward Current Transfer Ratio	Method 3076 V_{CE} =-2Vdc I_C = -5Adc			h_{FE}	30	90	- - -
Forward Current Transfer Ratio	Method 3076 V_{CE}= -2Vdc I_C = -10Adc			h_{FE}	20	- - -	- - -
Collector-to-emitter, Saturation voltage	Method 3071 IB = -1Adc I_C = -10Adc			$V_{CE}(sat)$	- - -	-0.40	Vdc

1* Methods referenced are contained in Standard MIL-STD-750

TABLE I. GROUP A INSPECTION

EXAMINATION OR TEST	CONDITIONS [1]	LTPD	MINIMUM REJECTION NUMBER	SYMBOL	LIMITS MIN.	LIMITS MAX.	UNITS
SUBGROUP 3 (Continued)		5	4				
Base to Emitter Saturation voltage	Method 3066 I_B = -1Adc I_C = -10Adc			$V_{BE}(sat)$	- - -	-0.90	Vdc
SUBGROUP 4		10	5				
Switching Time							
Rise Time				t_r	- - -	7.0	μsec
Storage Time	See Figure 2			t_s	- - -	3.0	μsec
Fall Time				t_f	- - -	5.0	μsec

1 Methods referenced are contained in Standard MIL-STD-750

TABLE II
GROUP B INSPECTION

EXAMINATION OR TEST	CONDITION [1]	LTPD	MINIMUM REJECTION NUMBER	SYMBOL	LIMITS MIN.	LIMITS MAX.	UNITS
<u>Subgroup 1</u>		20	4				
Physical Dimensions	Method 2066			- - -	- -	- -	- -
<u>Subgroup 2</u>							
Solderability	Method 2026	10	5	- - -	- -	- -	- -
Temperature Cycling	Method 1051 Cond. C $T_{MAX}=110^{+3}_{-0}$ °C			- - -	- -	- -	- -
Thermal Shock (Glass Strain)	Method 1056 Cond. A			- - -	- -	- -	- -
Moisture Resistance	Method 1021 Omit Initial Conditioning			- - -	- -	- -	- -
End Points:							
Collector to Base Current Cutoff	Method 3036 $V_{CBO}=-120$Vdc, $I_E = 0$			I_{CBO}	- -	-10	mAdc
Forward Current Transfer Ratio	Method 3076 $V_{CE}=-2$Vdc $I_C = -5$Adc			h_{FE}	[illegible]	120	- -
Collector to Emitter Saturation Voltage	Method 3071 $I_C= -10$Adc $I_B= -1$Adc			$V_{CE}(sat)$	- - -	-0.6	Vdc

1* Methods referenced are contained in Standard MIL-STD-750

TABLE II
GROUP B INSPECTION - Continued

EXAMINATION OR TEST	CONDITION [1*]	LTPD	MINIMUM REJECTION NUMBER	SYMBOL	LIMITS MIN.	LIMITS MAX.	UNITS
Subgroup 3 Shock [2,3]	Method 2016 Nonoperating 1500 g, 0.5msec 5 blows each in orientations X_1, X_2, Y_1 and Y_2 (total 20 blows)	10	5	- - -	- -	- -	- - -
Constant Acceleration [2]	Method 2006 10,000 G			- - -	- -	- -	- - -
Vibration Fatigue [2,3]	Method 2046 20 G			- - -	- -	- -	- - -
Vibration Variable Frequency [2,3]	Method 2056 20 G			- - -	- -	- -	- - -
End Points: (Same as for Subgroup 2)							
Subgroup 4 Barometric Pressure Reduced	Method 1001 Pressure=15mmHg t = 60 seconds	20	4	- - -	- -	- -	- - -
End Points: Collector to Base Cutoff Current	Method 3036 VCB =-120Vdc IC = 0			I_{CEO}	- -	-10	mAdc
High Temperature Operation	$T_c = 85^\circ$ C			- - -	- -	- -	- - -
Collector to Base Cutoff Current	Method 3036 VCB =-120Vdc IE = 0			I_{CBO}	- -	-10	mAdc

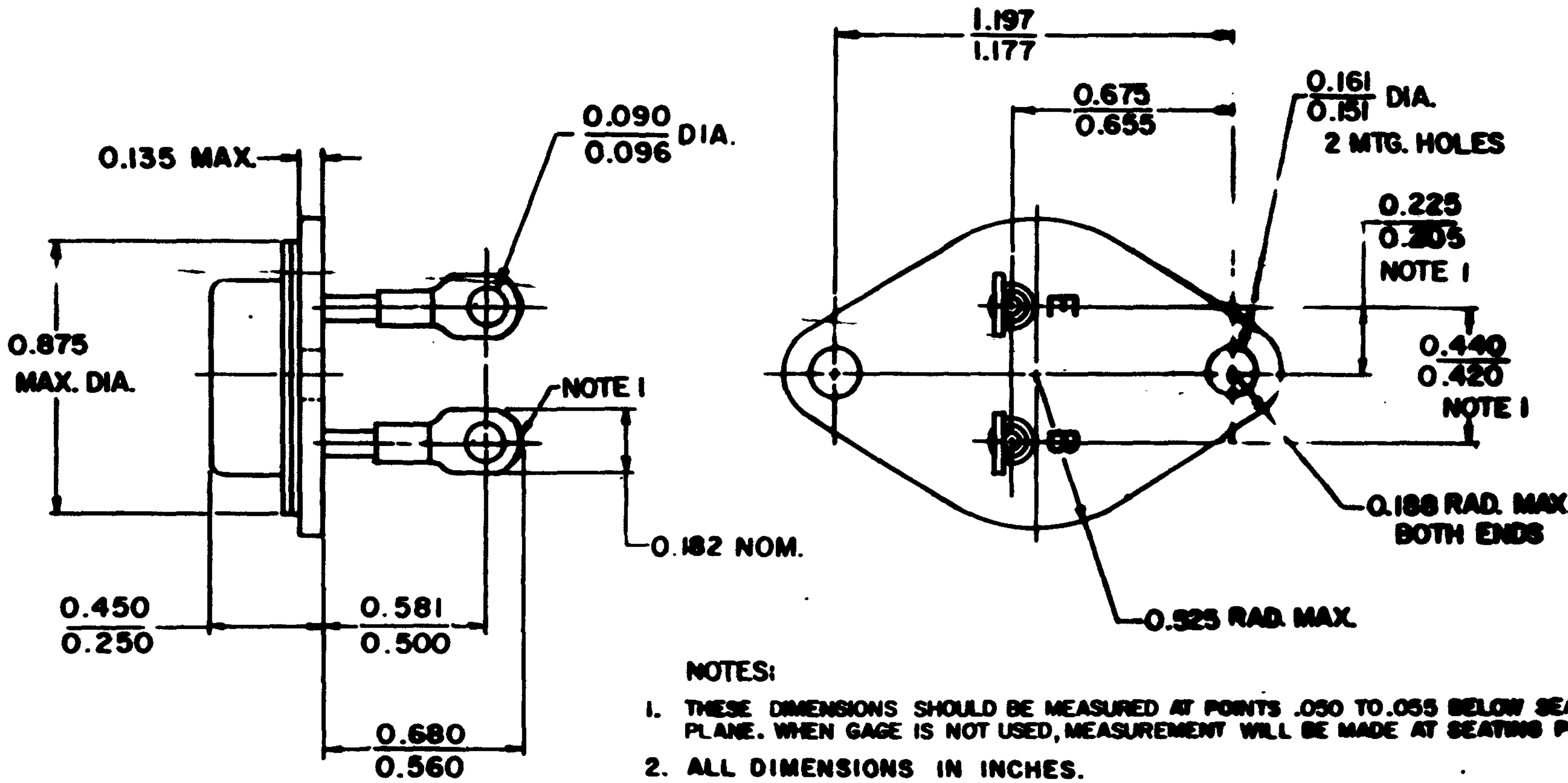
1* Methods referenced are contained in Standard MIL-STD-750

2. Destructive Tests
3. Non-Operating

TABLE II
GROUP B INSPECTION

EXAMINATION OR TEST	CONDITION	LTPD	MINIMUM REJECTION NUMBER	SYMBOL	LIMITS MIN.	LIMITS MAX.	UNITS
SUBGROUP 5 Salt Atmosphere	Method 1041 Cond. B	20	4	- - -	- -	- -	- -
SUBGROUP 6 Thermal Resistance Junction to Case	Method 3126	20	4	- - - Θ_{J-C}	- - - -	- - 1.2	- - $^{o}C/W$
SUBGROUP 7 High Temperature Life (Nonoperating)	Method 1031 $T_A = 110 {}^{+10}_{-5} {}^{o}C$	$\lambda = 15$					
End Points: Collector to Base Cutoff Current	Method 3036 VCB =-120Vdc IE = 0			ICBO	- -	-10	mAdc
Forward Current Transfer Ratio	Method 3076 VCE = -2Vdc IC = -5Adc			h_{FE}	20	120	- -
Collector to Emitter Saturation Voltage	Method 3071 IC = -10Adc IB =-1Adc			VCE (Sat)	- -	-0.6	Vdc
SUBGROUP 8 Accelerated Life Test High Temperature (Non Operating)	Method 1031 $T_A = 150^{o}C {}^{+0}_{-5} {}^{o}C$	$\lambda = 25$					
End Points: (Same as SUBGROUP 7)							
SUBGROUP 9 Operation Life Steady State	VCE = -24Vdc Pd = 20W $T_{CASE} = 85^{o}C {}^{+0}_{-3} {}^{o}C$	$\lambda = 15$					
End Points: (Same as for SUBGROUP 7)							

TRANSISTOR OUTLINE
TO-41



NOTES:

1. THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050 TO .055 BELOW SEATING PLANE. WHEN GAGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.
2. ALL DIMENSIONS IN INCHES.

FIGURE 1

MIL-S-19500/

RISE, FALL, STORAGE TIME

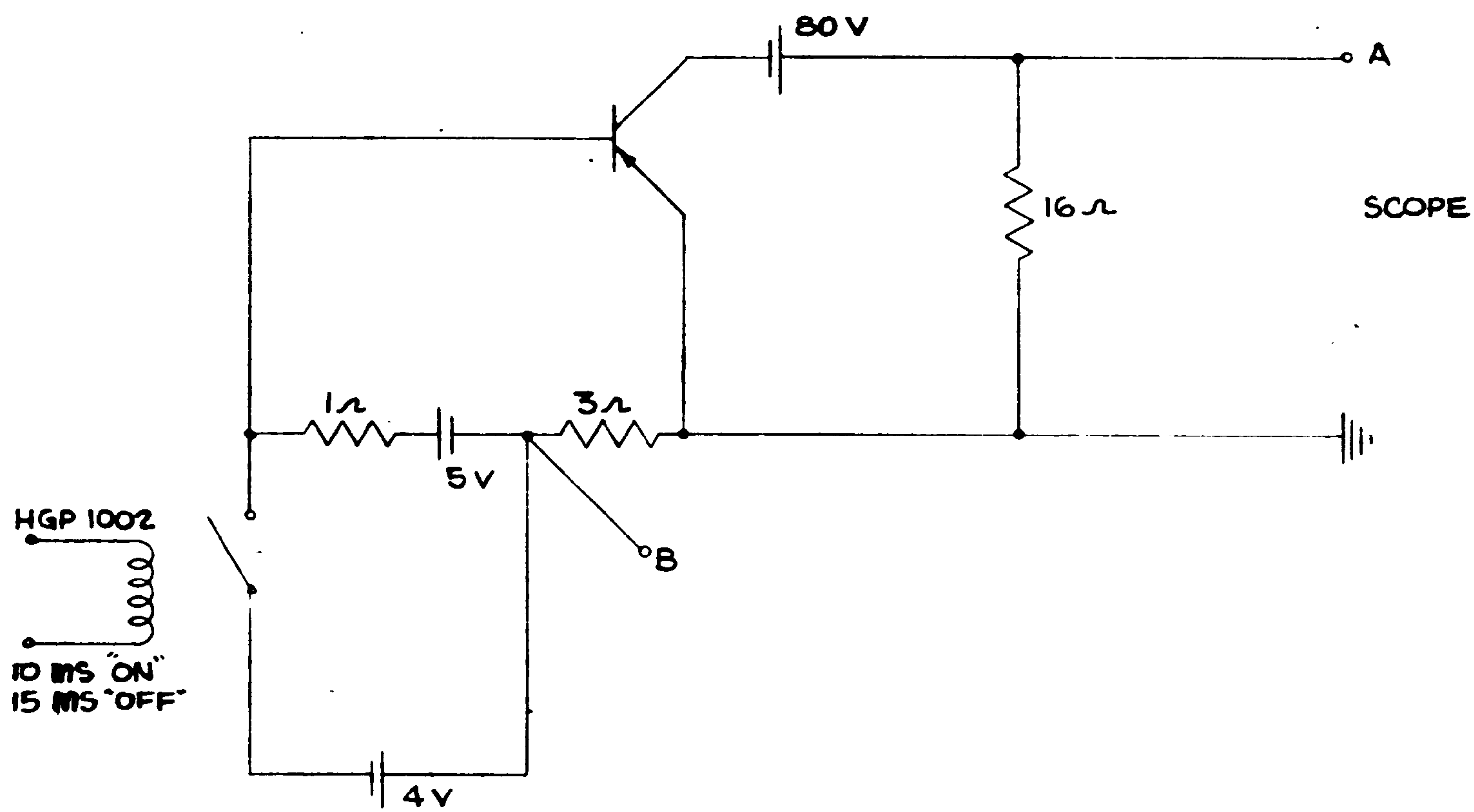
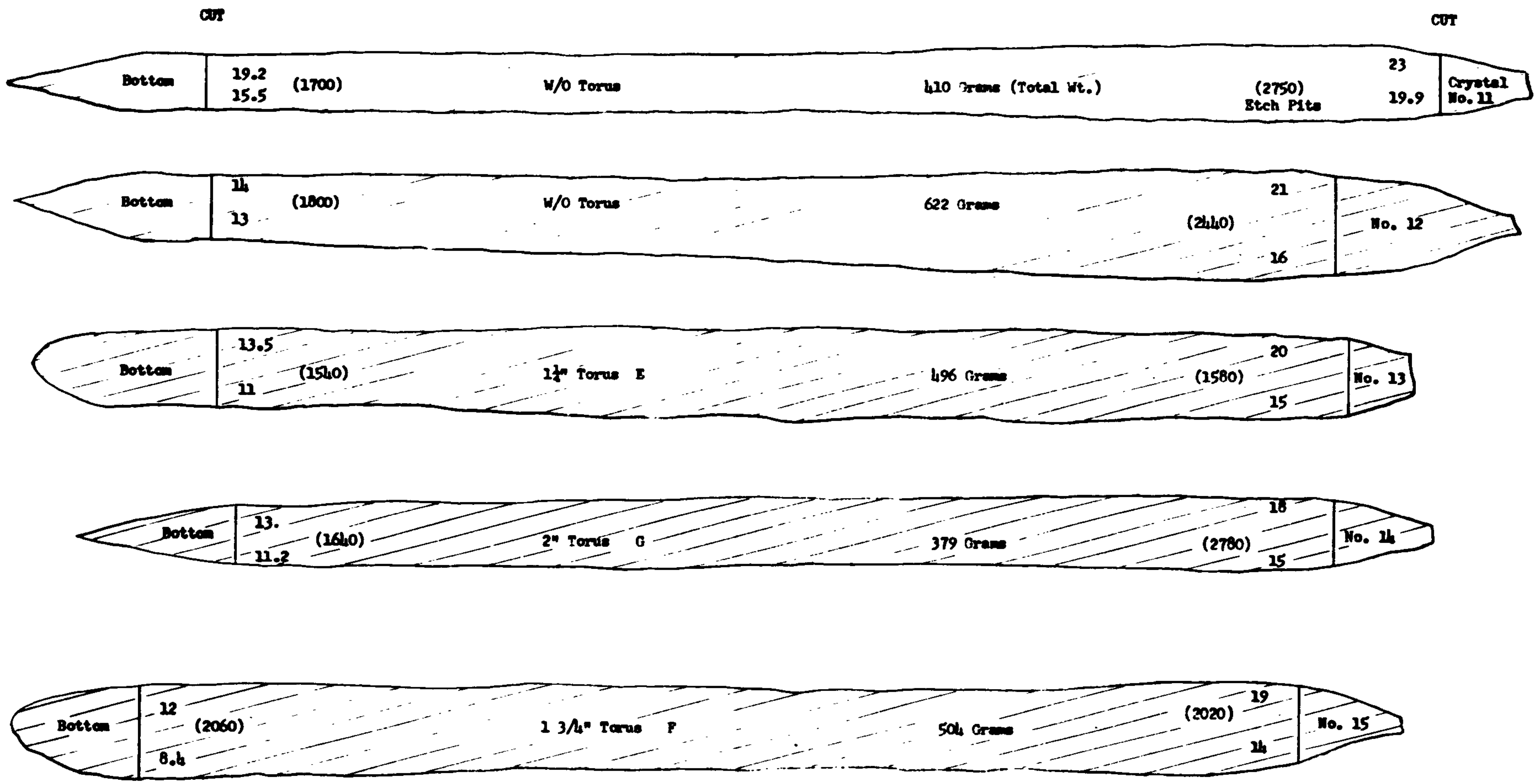


FIG 2

FIGURE 2 Shadowgraphs of Crystal Nos. 11 to 15
(Floating Crucible Furnace)



Total Wt. Sx = 2410 Grams
Less Ends 401 Grams
Net = 2009 Grams
Resistivity Reject = 384 Grams
Good Crystal = 1625 Grams
81% Yield (20-10 Ohm CM Mat'l)

DATA SHEET AND CONTROL CHART

PRODUCT	10A DAP DICE F2-99
CHARACTERISTIC	THICKNESS
TEST CONDITIONS	AFTER ETCH
MEAS. INSTRUMENT	MICROMETER

FIGURE 2 (1.1.4)

THE BENDIX CORPORATION
SEMICONDUCTOR PRODUCTS

SHEET ___ OF ___ SHEETS

ENG.

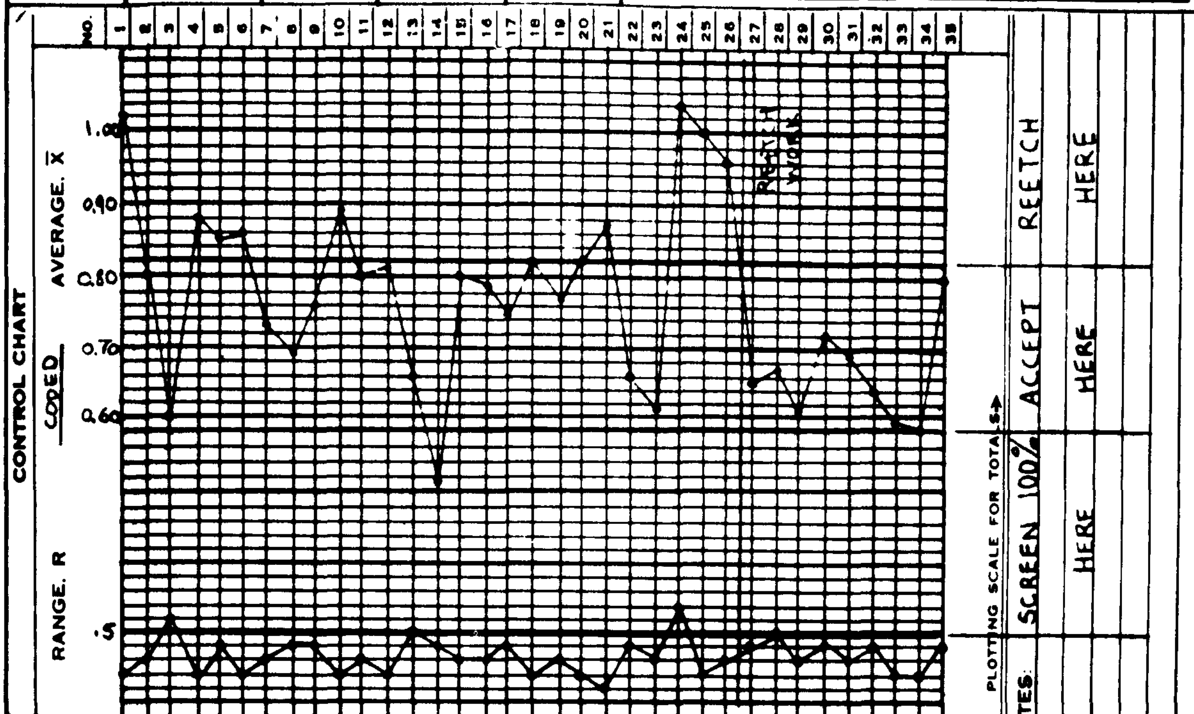
DEPT.

DATE

CONTROL CHART CONSTANTS	SAMPLE SIZE	$CL\bar{X}$	CL_R	EST σ'
	4	$\bar{X} \pm .729\,\bar{R}$	$2.28\,\bar{R}$	$.486\,\bar{R}$
	5	$\bar{X} \pm .577\,\bar{R}$	$2.11\,\bar{R}$	$.430\,\bar{R}$

UNIT OF MEAS: MIL

SPEC LIMITS: AVG 0.58 - 0.82



SUMMARY

NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
AVERAGE $\bar{X}$ (or Total)	1.02	0.80	0.60	0.88	0.85	0.86	0.73	0.69	0.76	0.89	0.80	0.81	0.66	0.51	0.80	0.79	0.75	0.82
RANGE R	.2	.3	.6	.2	.4	.2	.3	.4	.4	.2	.3	.2	.5	.4	.3	.3	.4	.2

NO	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	TOT
AVERAGE $\bar{X}$ (or Total)	0.77	0.82	0.87	0.66	0.61	1.04	.00	0.96	0.65	0.67	0.61	0.72	0.69	0.64	0.59	0.58	0.80	
RANGE R	.3	.2	.1	.4	.3	.7	.2	.3	.4	.5	.3	.4	.3	[illegible]	.2	.2	.4	

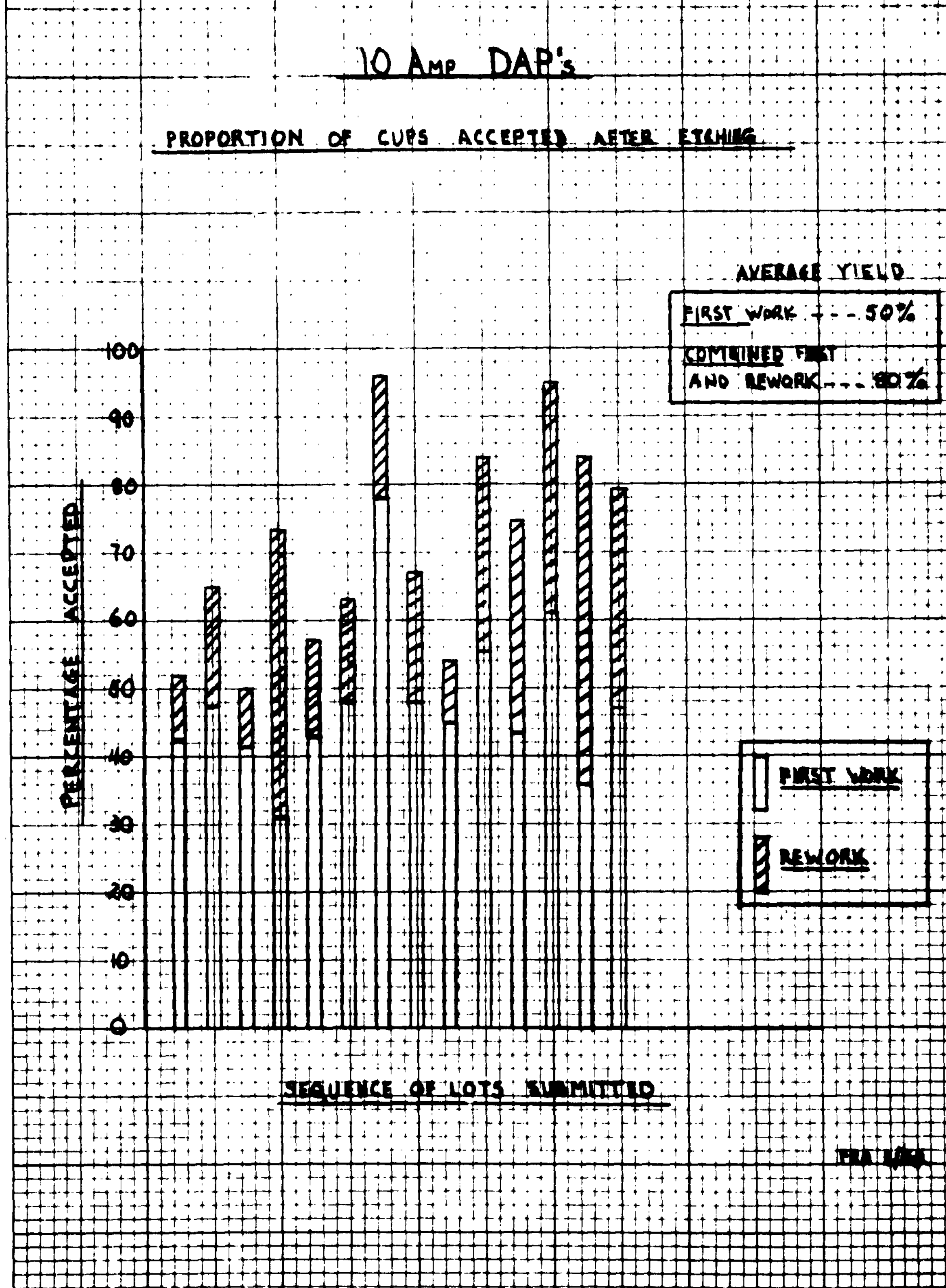
$\bar{R}$ =
CL_R =
$\bar{X}$ =
$CL\bar{X} = \bar{X} \pm$
$UCL\bar{X}$ =
$LCL\bar{X}$ =
EST σ'ₐ =

DATA SHEET

DATE	Sample No.							
	1	2	3	4	5	6	7	TOTAL
	8	9	10	11	12	13	14	
	15	16	17	18	19	20	21	
	22	23	24	25	26	27	28	
	29	30	31	32	33	34	35	

RE-ETCH

FIGURE 3. (1.1.4)



10 Amp DAP's
PROPORTION OF CUPS ACCEPTED AFTER ETCHING
AVERAGE YIELD
FIRST WORK - - - 50%
COMBINED FIRST AND REWORK - - - 80%
PERCENTAGE ACCEPTED
100
90
80
70
60
50
40
30
20
10
0
FIRST WORK
REWORK
SEQUENCE OF LOTS SUBMITTED

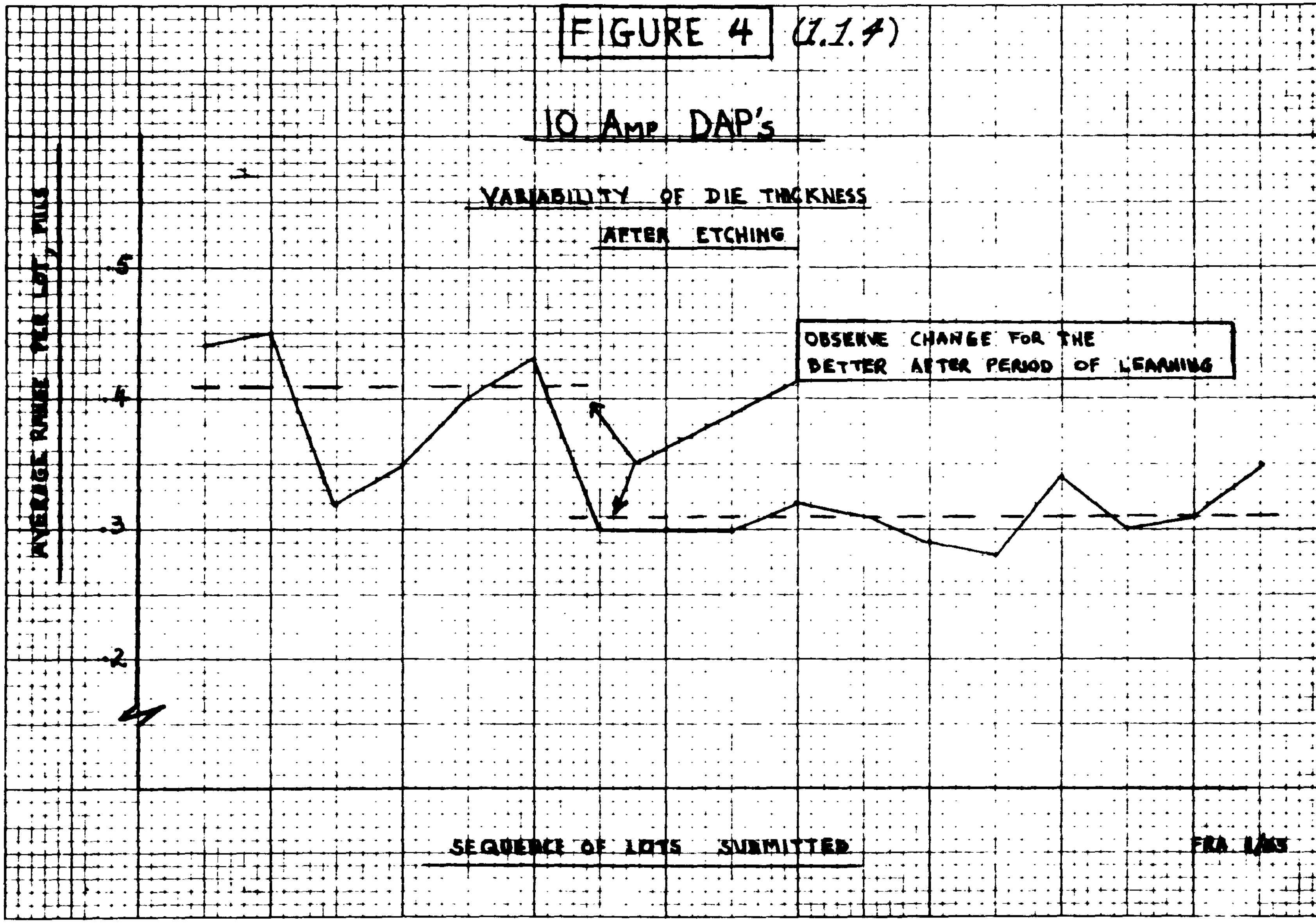


FIGURE 4 (1.1.4)
10 Amp DAP's
VARIABILITY OF DIE THICKNESS
AFTER ETCHING
OBSERVE CHANGE FOR THE
BETTER AFTER PERIOD OF LEARNING
AVERAGE RANGE PER LOT, MILS
.5
.4
.3
.2
SEQUENCE OF LOTS SUBMITTED
FRA 1/65

INDUCTIVE SWEEP TEST

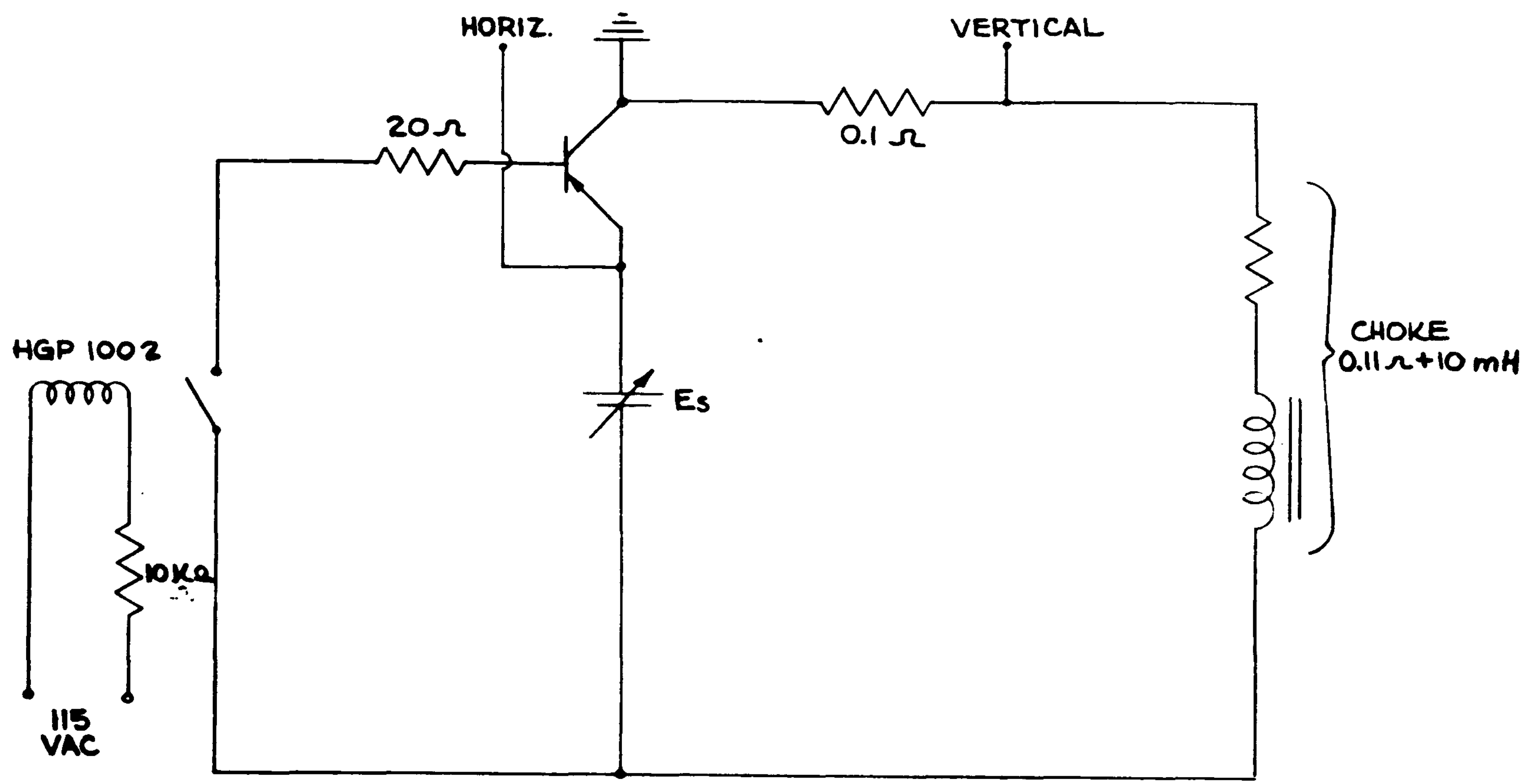


FIG 5

RISE, FALL, STORAGE TIME

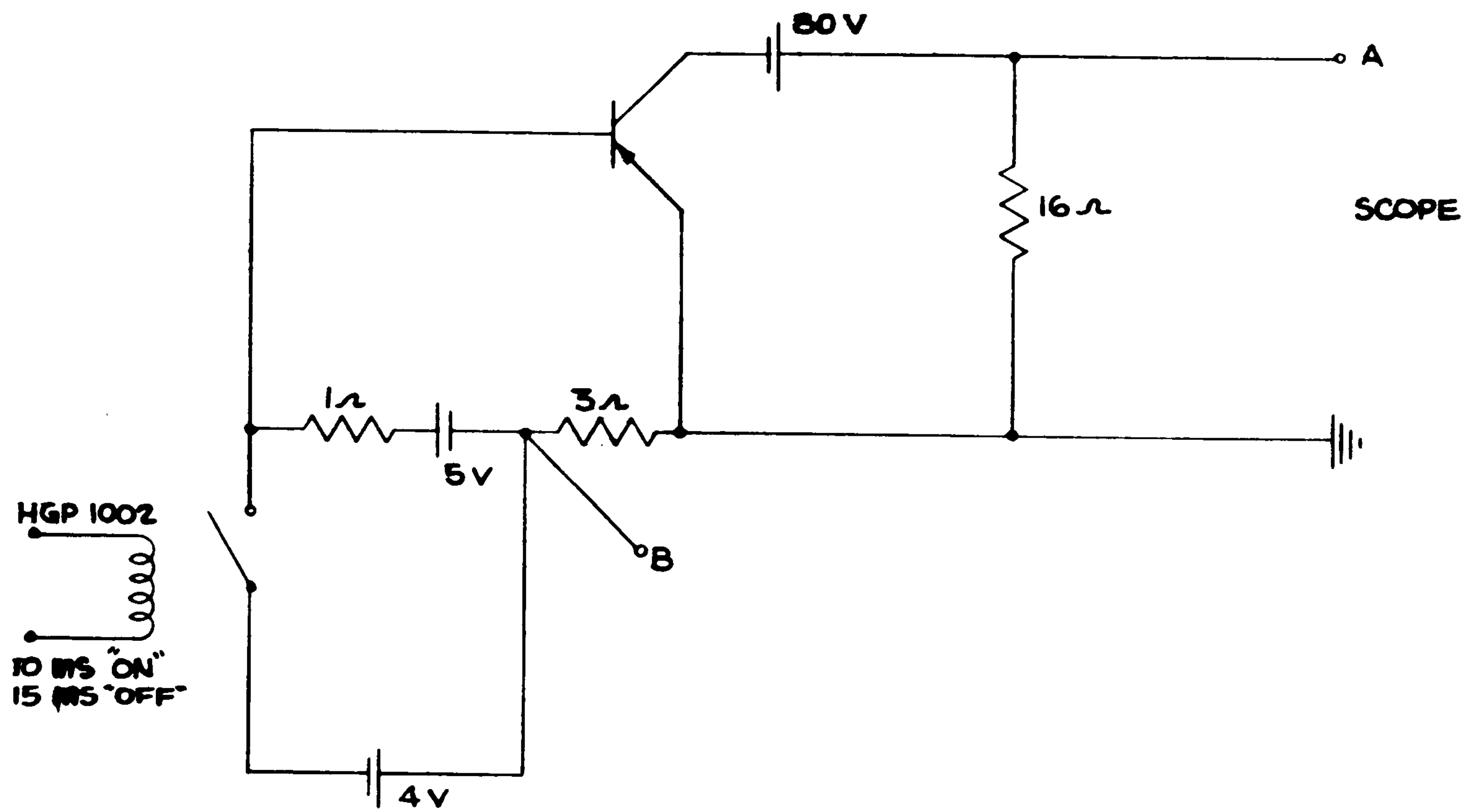
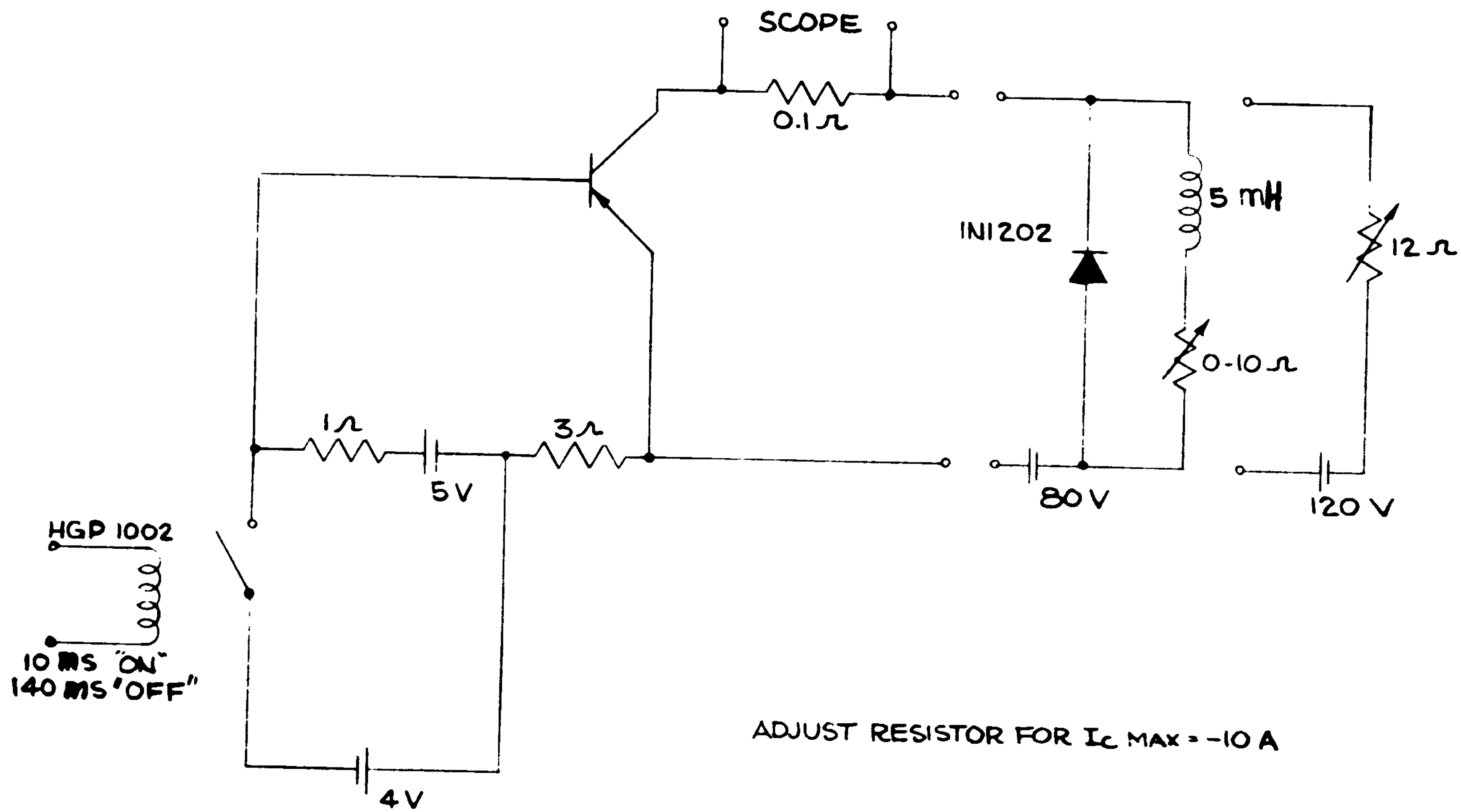


FIG 6

LOAD LINE SWITCHING TEST:



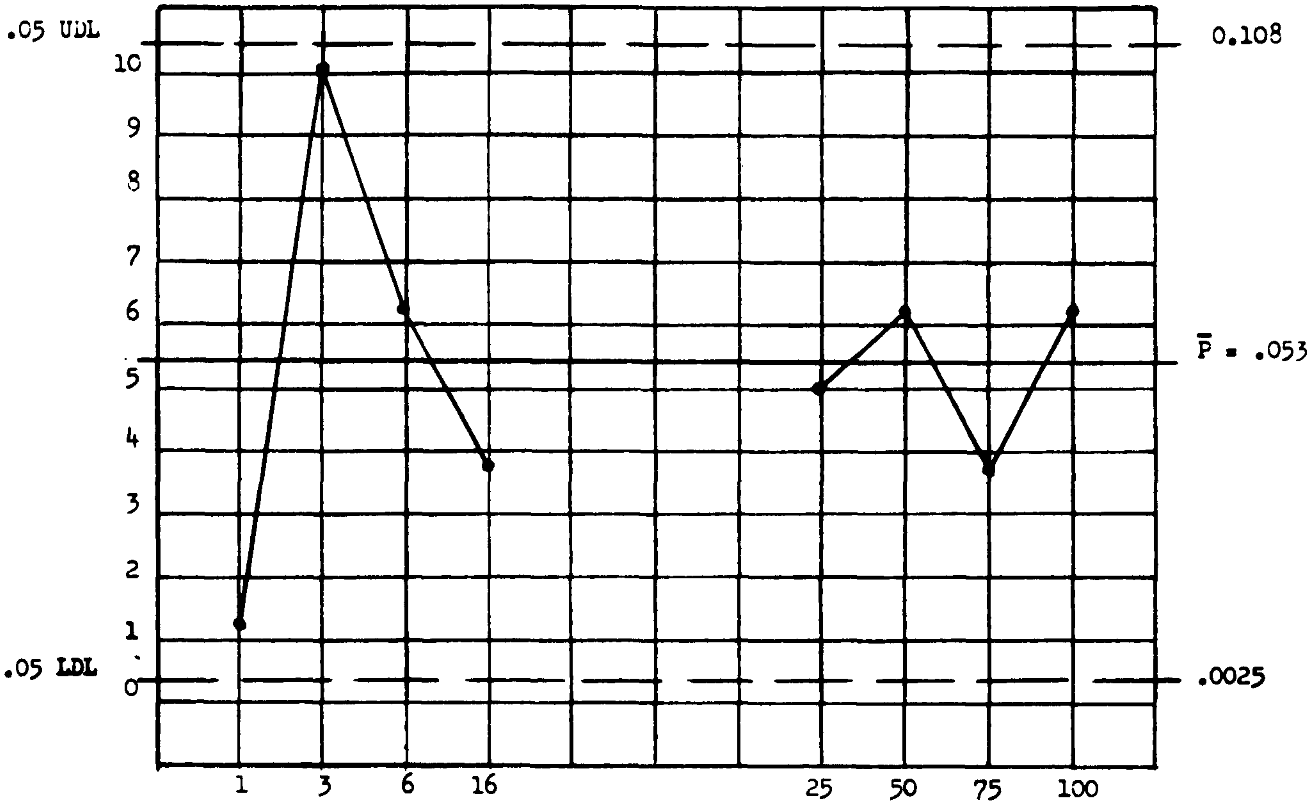
ADJUST RESISTOR FOR I_C MAX = -10 A

FIG 7

HELIUM LEAK DETERMINATION

ANALYSIS OF MEANS[1]

FIGURE 8



Where: $\bar{P} = 17/320 = .053$ (From Table VIII)

$\sigma = \sqrt{\frac{.053 \times .95}{80}} = 0.0258$

$h_{.05} = 2.15$ [1]

$5\% DL = \bar{p} \pm h_{.05}\,\sigma$

5% UDL = Upper Decision Limit = .053+2.15x.0258=+0.108

5% LDL = Lower Decision Limit = .053-2.15x.0258=-0.0025

1 Reference Technical Report No. 2, February 10, 1960, prepared by Ellis R. Ott and Sidney S. Lewis, Rutgers University, New Brunswick, N. J. for Army, Navy and Air Force under Contract Nonr 404 (11), (Task NR-42-021) with the Office of Naval Research.

REPEATABILITY STUDY

UNIT TO UNIT COMPARISON

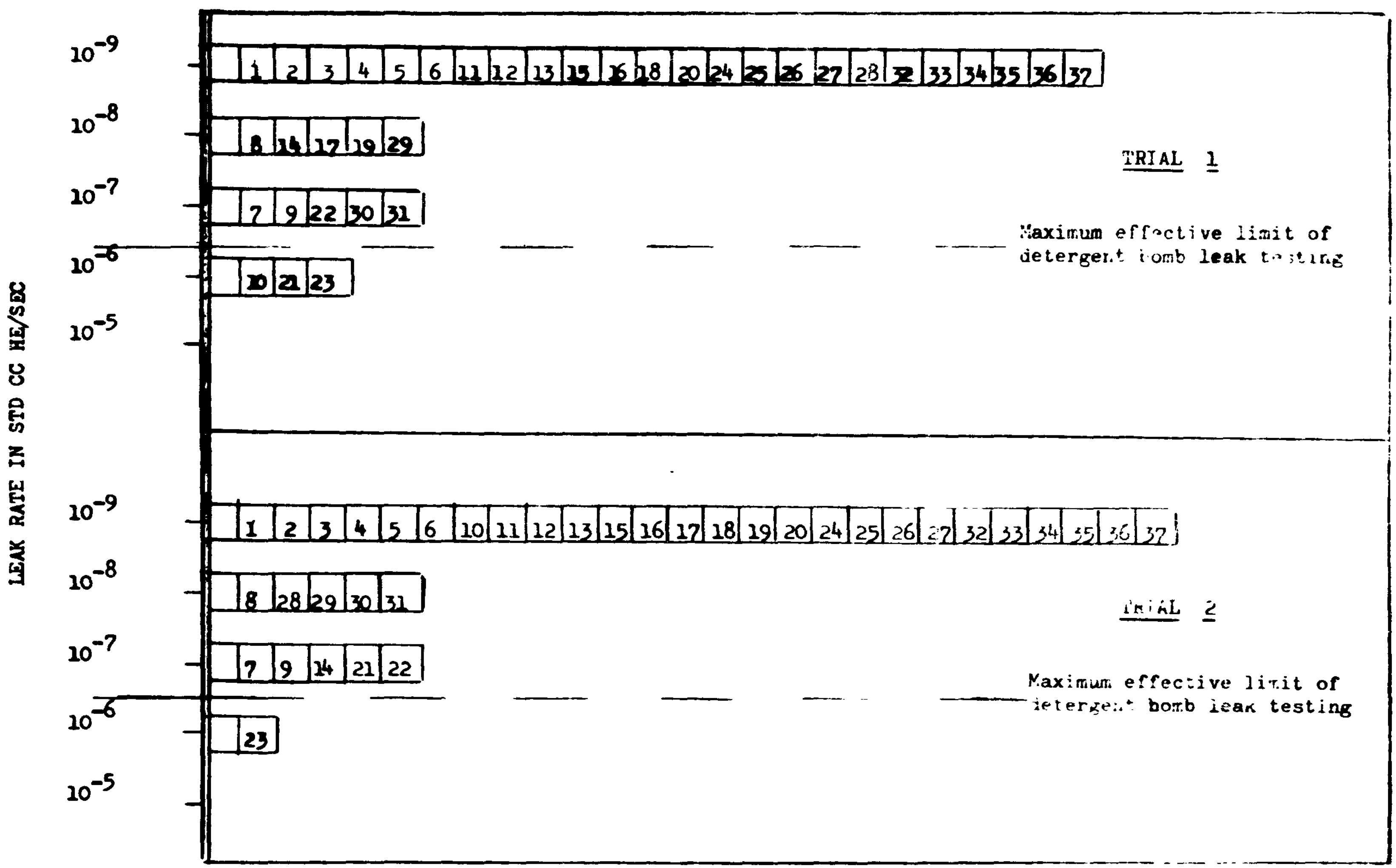


FIGURE 9

IV - APPENDIX I

Reliability Test Program

1. Reliability Life Testing: Life tests have been conducted on the standard product and this data will be used as a control for the evaluation of the production improvements. It is expected that all the product improvements will be completed and incorporated for production runs during the 4th Quarter.

Appendix I-A shows each of the following tests conducted for a 1000 hour period: Storage life tests at 25°C and 110°C, operating life test with the case temperature at $85^{\circ}\,{}^{+0}_{-3}{}^{\circ}C$ and a collector power dissipation of 30 watts. The dissipation of 30 watts with a Vcb=-25Vdc is such that the transistor element is at the maximum rated temperature of 110°C.

Measurements were taken at 250, 500, 750 and 1000 hours. Data was taken on the following parameters:

Icbo @ Vcb = 100 volts

BVcer @ Ic = 50mA Rbe = 100Ω

BVebo @ 50mA

Ib @ Vce = 2V
Ic = 5A

For the purpose of illustrating the product behavior as a result of aging stresses, data for each of the above mentioned parameters is presented both in percentile and frequency distribution form given in Appendix II. This data has also been reviewed and the median values are shown.

Similar data is presented for the operating power dissipation life test.

Electrical design test data for the above mentioned parameters is also included as Appendix I-B. This design test data represents information on raw material and is indicative of the process control. This data is presented for ten (10) consecutive production lots ending with date code 252.

Extended life test data for the Bendix 10 Ampere DAP Generic family, from which the 2N1430 transistor is selected is presented. This life test represents an evaluation of 100 transistors for a period of 10,000 hours.

Failure rate information has been accumulated on the basis of the aforementioned life tests and also from information compiled from previous life tests which were performed at 100, 135 and 155°C. This information is presented as a cumulative failure rate curve as shown in Appendix I-A. Examination of the failure rate curve indicates the failure rate to be 0.09%/1000 hours at 25°C, 0.8% at 110°C and 1.7% at 150°C.

Additional step stress life test information also presented in terms of cumulative failure rate vs temperature in $\frac{1}{T}$o is shown in Appendices I-C1, I-C2, and I-C3. These tests were conducted over a temperature range of 100 to 320°C with failure of all devices intended. Tests were performed on 2N1430 devices each drawn from regular productions at two month intervals during the period July 1962 through January 1963. Step stress testing in all cases included an ascending temperature stress in 10°C steps with a storage period of two hours at each step. After each storage period the units were cooled to room temperature and the parameters were recorded.

Failure rate curves for all except Report No. 1 were derived utilizing the following limits:

Δ Icbo < 50%

Δ Ib(hfe) < 30%

Icer @ -80V < 75 μAdc

Iebo @ -1.5V < 75 μ Adc

Failure rate for Report No. 1 samples was calculated in terms of inoperable devices only.

2. Reliability Demonstration Program.

The program from the fourth quarter on to completion will be to place transistors, manufactured with the various product improvements on reliability life tests for the purpose of demonstrating the device capability of meeting a maximum failure rate of 0.05%/1000 hours at a 90% confidence level.

For this goal, a close lot control system will be established, and the associated data will be analysed and prepared for any failure analysis which would be required. It is our intent to monitor the reliability testing on a lot by lot basis, using the step stress technique and extended life testing.

The information gained on the data from the step stress (accelerated) testing will reveal useful information about the aging characteristics and reliability of the transistor. The information accumulated by such stress tests agrees well with the more conventional aging tests at the lower stresses and longer times.

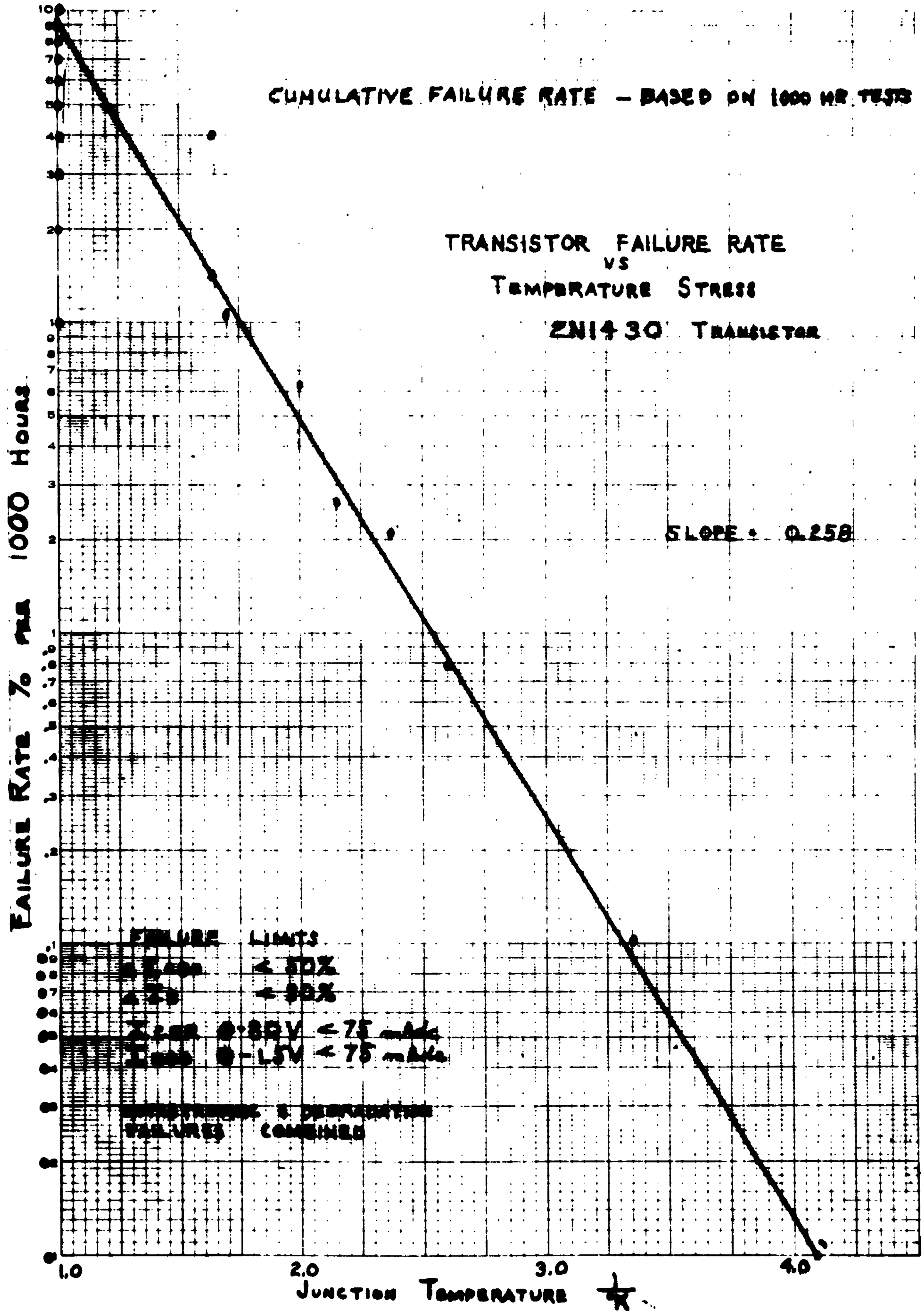
The demonstration of normal distribution of failures in reciprocal temperature (absolute) and the log-normal distribution of failures in time along with the constant variance for these distributions will illustrate some physical model for device degradation.

The relatively short time and small number of devices needed, along with failure of the complete sample, makes this technique useful in many ways, such as:

1. A rapid comparison evaluation.
2. Process control and evaluation.
3. Day to day or lot to lot production variations.

The complete knowledge of the statistics allows separation of the number of mavericks and also in conjunction with the acceleration curve enables the predication of percent failures versus stress and time. The immediate result of the test to failure yields a sufficient number of failed devices to perform a "failure analysis," not only on the weak devices but also the better devices to determine the cause of failure.

The physical nature of the applied stresses and the interaction of the stresses will have to be investigated for a thorough device evaluation. This acceleration testing will be adopted for all the stresses involved.



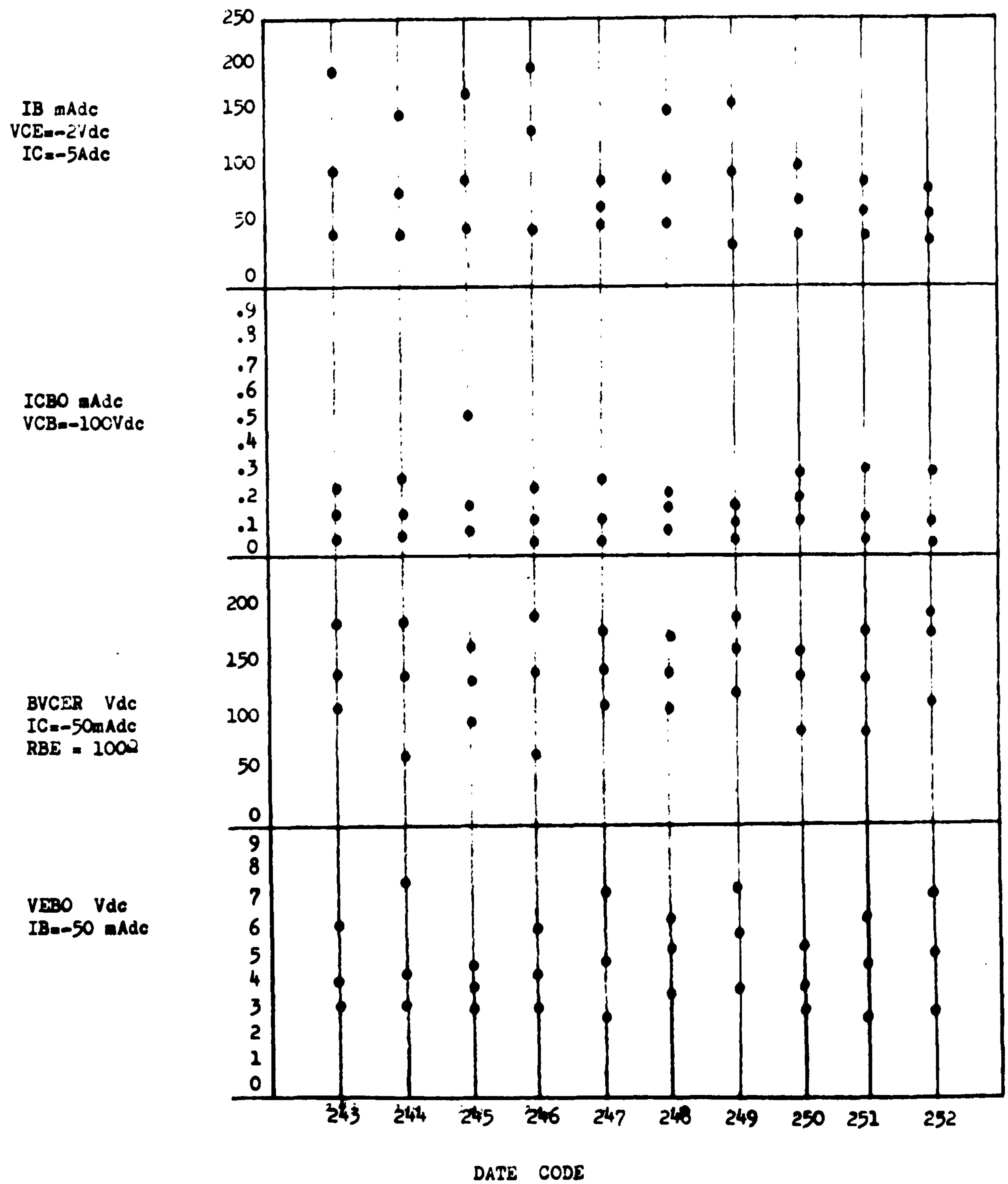
CUMULATIVE FAILURE RATE — BASED ON 1000 HR TESTS
TRANSISTOR FAILURE RATE
VS
TEMPERATURE STRESS
2N1430 TRANSISTOR
SLOPE = 0.258
FAILURE LIMITS
FAILURE RATE % PER 1000 HOURS
1.0
2.0
3.0
4.0
JUNCTION TEMPERATURE

APPENDIX I-B

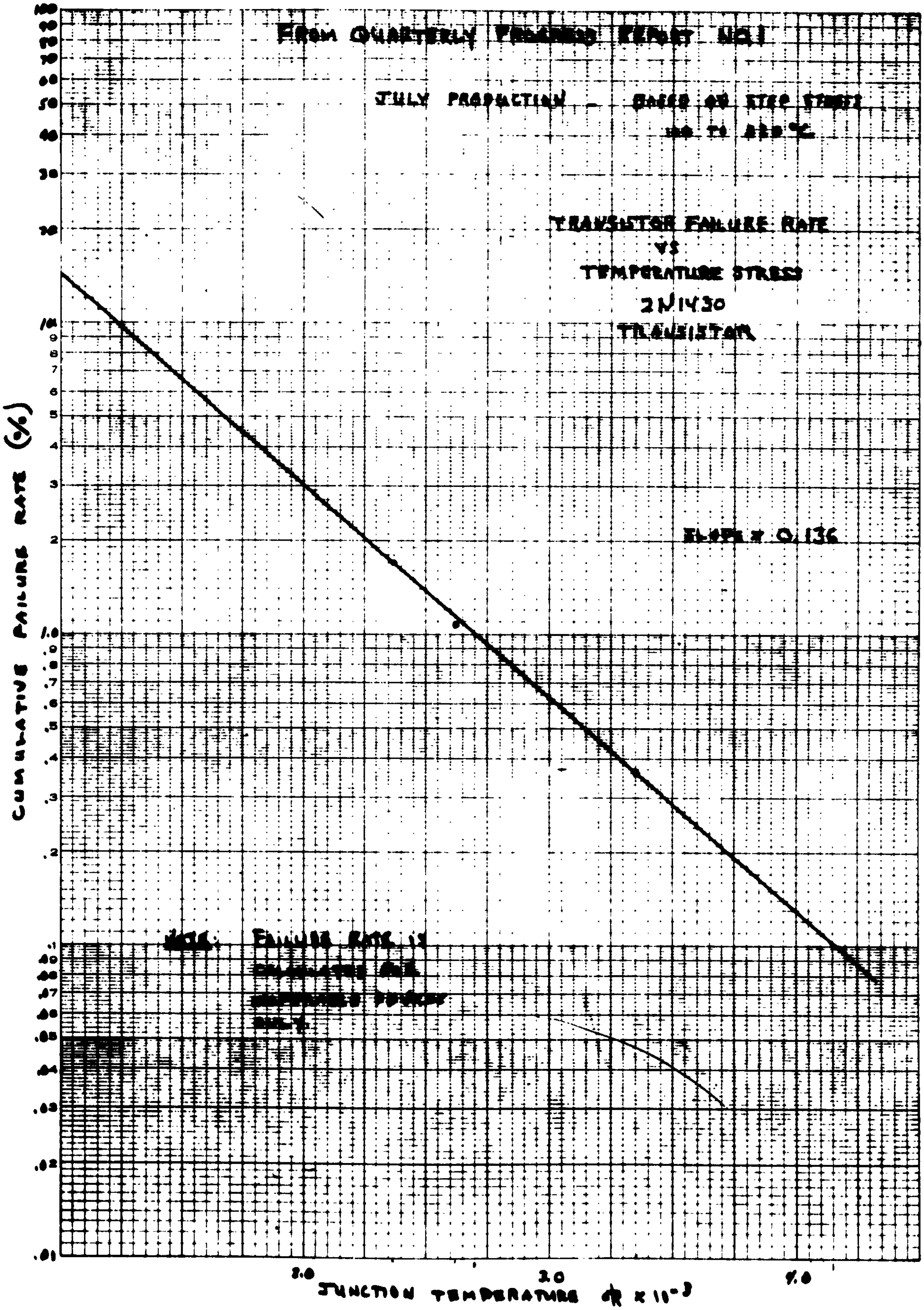
THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION

TRANSISTOR TYPE 2N1430

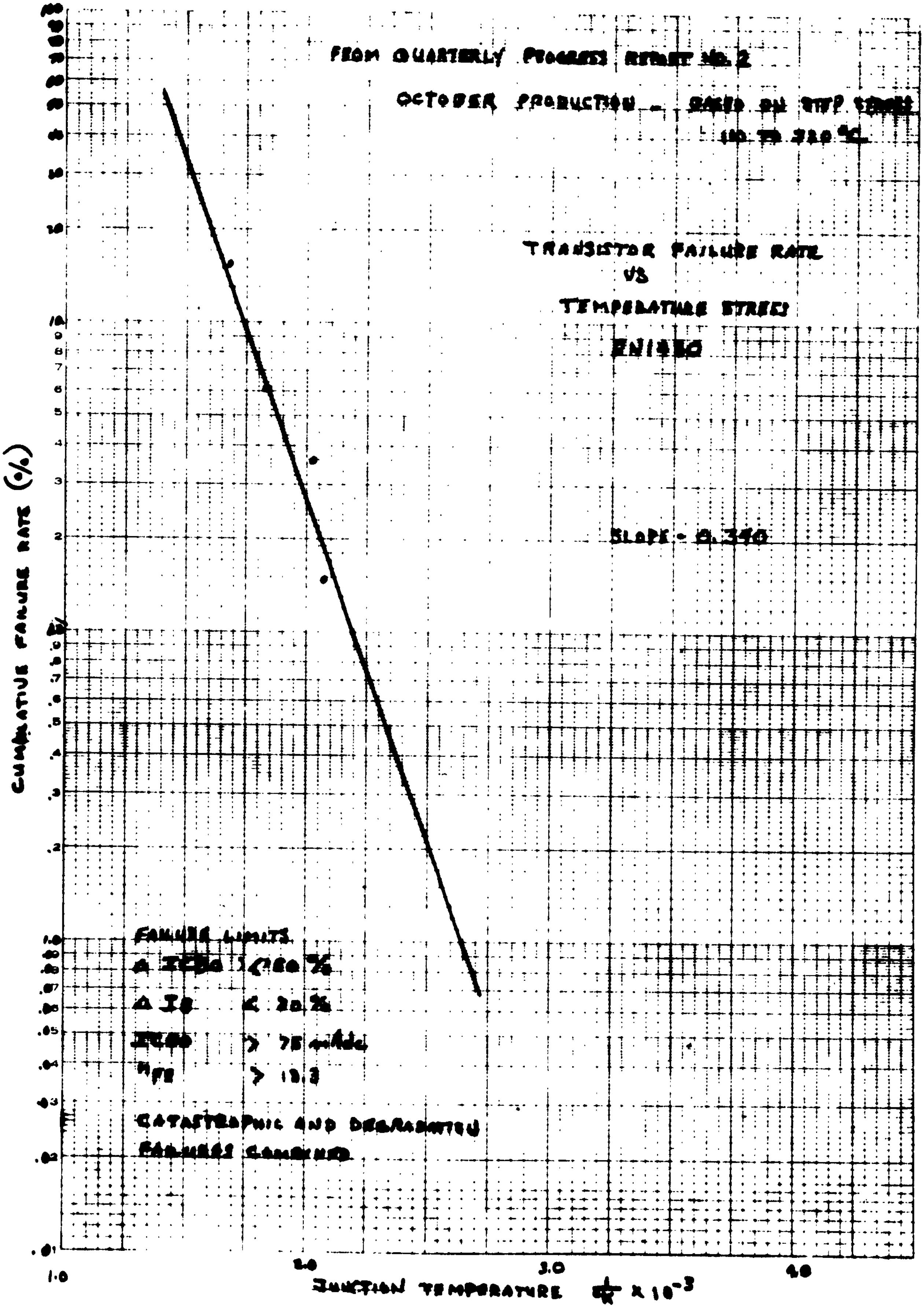
ELECTRICAL DESIGN TEST DATA

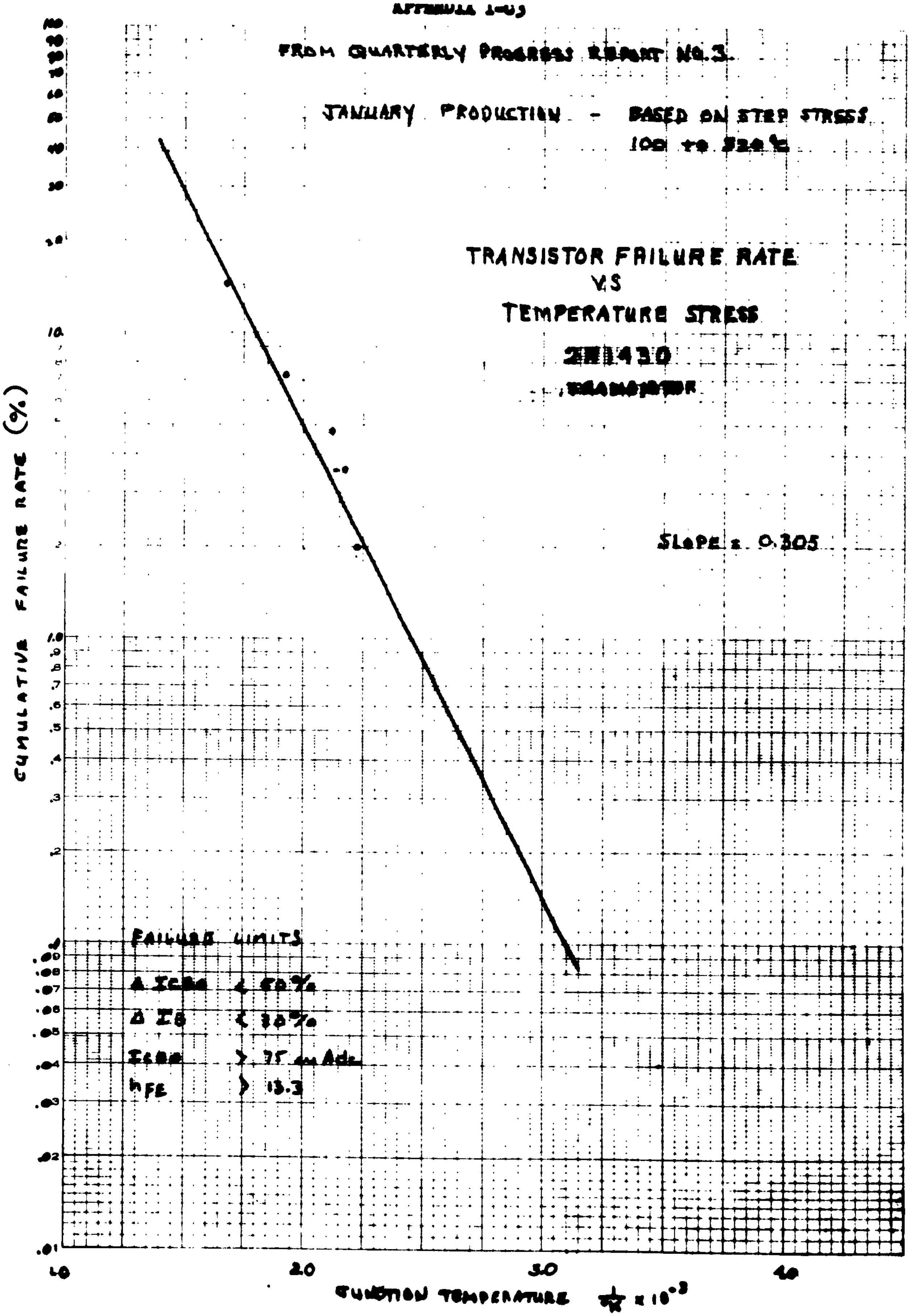


APPENDIX I-01



APPENDIX I-02




FROM QUARTERLY PROGRESS REPORT NO.3.
JANUARY PRODUCTION - BASED ON STEP STRESS
TRANSISTOR FAILURE RATE
VS
TEMPERATURE STRESS
SLOPE = 0.305
CUMULATIVE FAILURE RATE (%)
FAILURE LIMITS
hFE > 13.3
1.0
2.0
3.0
4.0
JUNCTION TEMPERATURE

IV. - APPENDIX II

Life Test Presentations

Storage and operating life test were performed to monitor and determine the stability of devices for periods of 1000 hours. Extended life test information on 100 transistors tested for 10,000 hours is also shown.

With each parameter both the percentile information and histogram graphs are given. The percentile presentations illustrate distribution behavior from one reading period to the next. Histograms for each parameter illustrate the shift in characteristic value for 250 hour increments.

THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION

TRANSISTOR TYPE 2N1430

APPENDIX II

PARAMETER DISTRIBUTION

TYPE: 10 AMPERE DAP

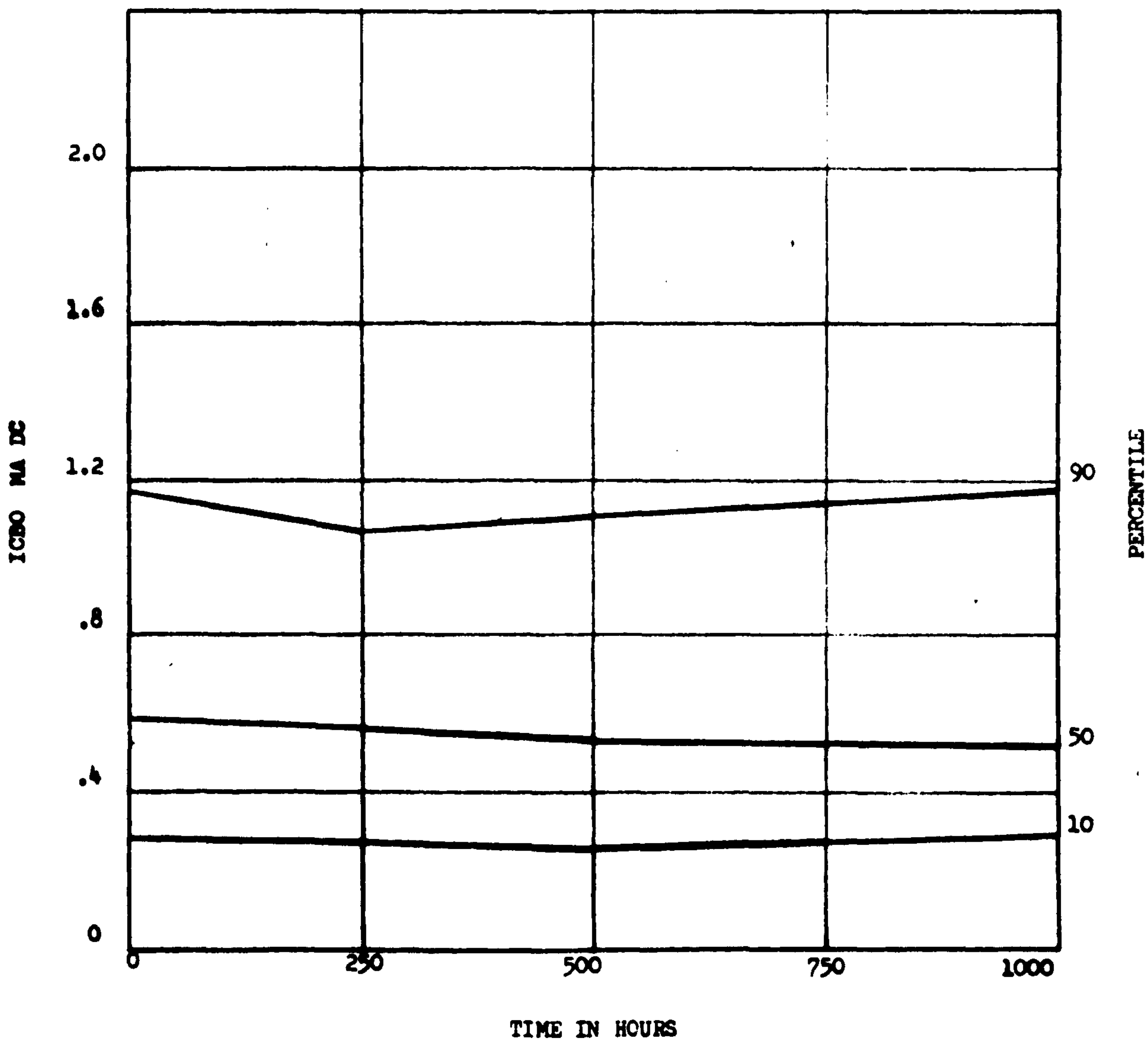
STRESS: STORAGE LIFE - 1000 Hours at 25° C

PARAMETER: ICBO

TEST CONDITIONS: VCB = -100 Vdc

INITIAL LIMIT: -50 MA dc Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

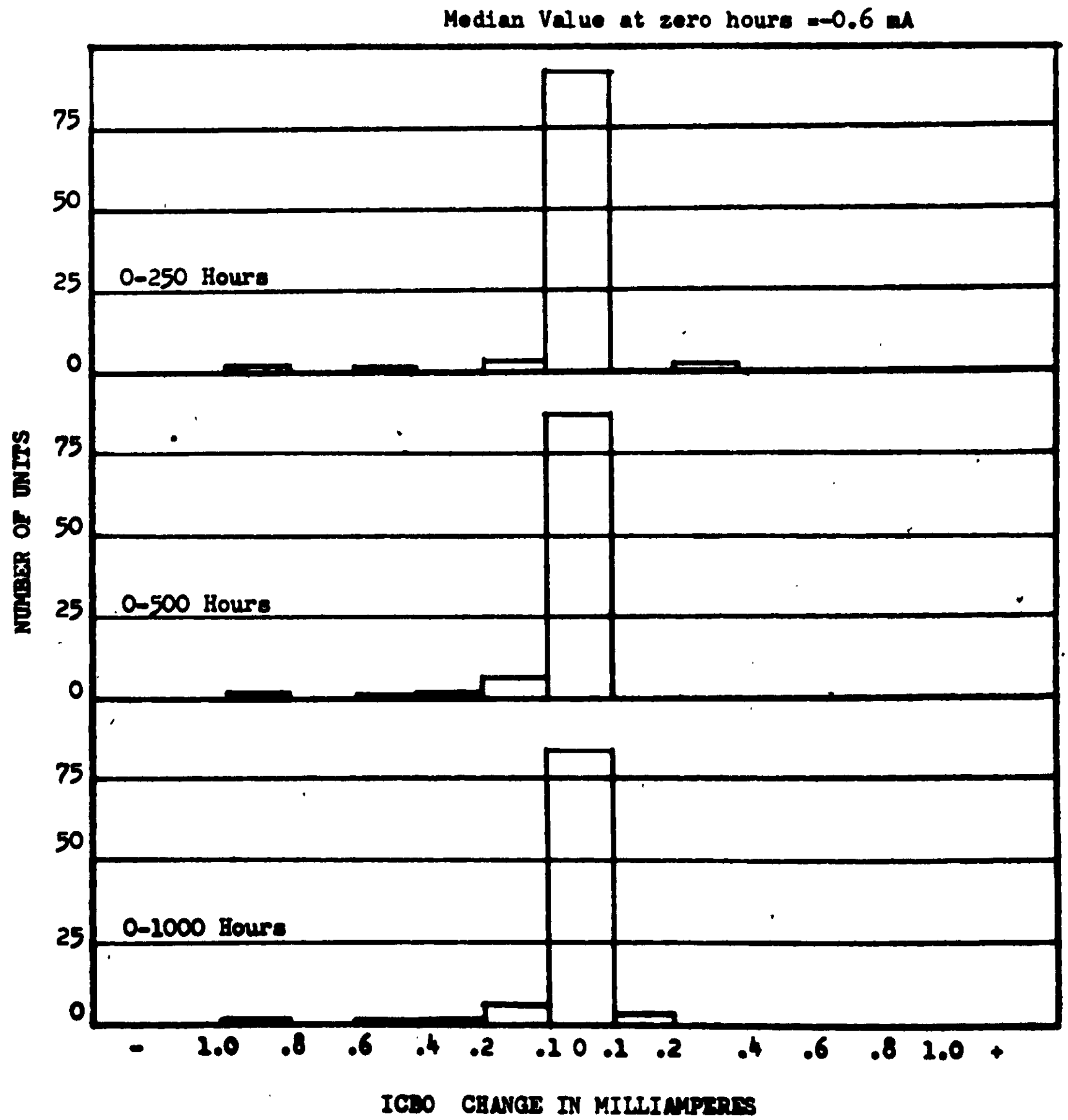
STRESS: 25° C STORAGE LIFE

PARAMETER: ICBO

TEST CONDITIONS: VCB = -100 Vdc, IE = 0

INITIAL LIMIT: -50 MA DC Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION

TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

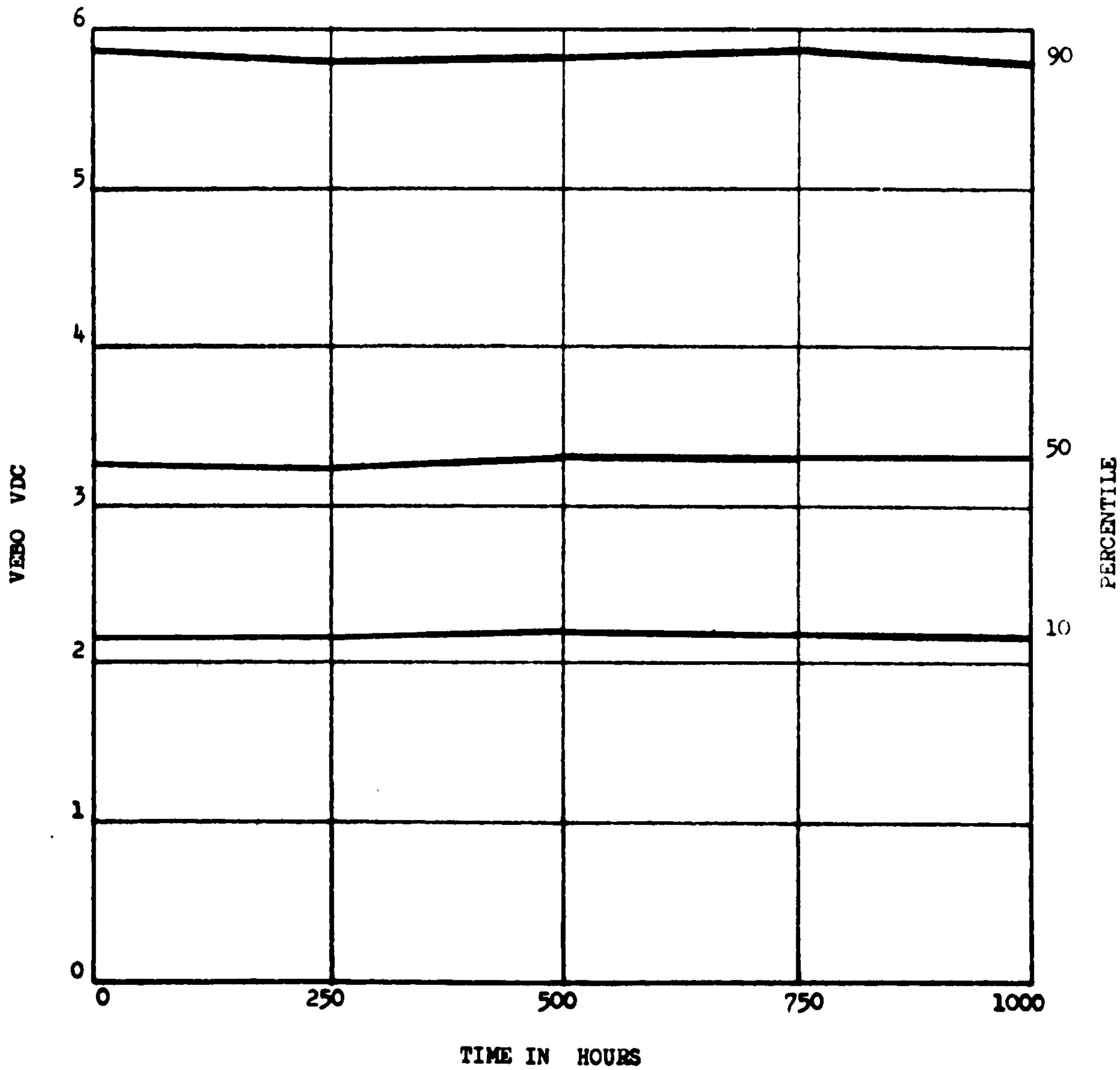
STRESS: STORAGE LIFE - 1000 Hours at 25° C

PARAMETER: VEBO

TEST CONDITIONS: IEB = -50 MA DC

INITIAL LIMIT: -.5 Vdc Min.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION

TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

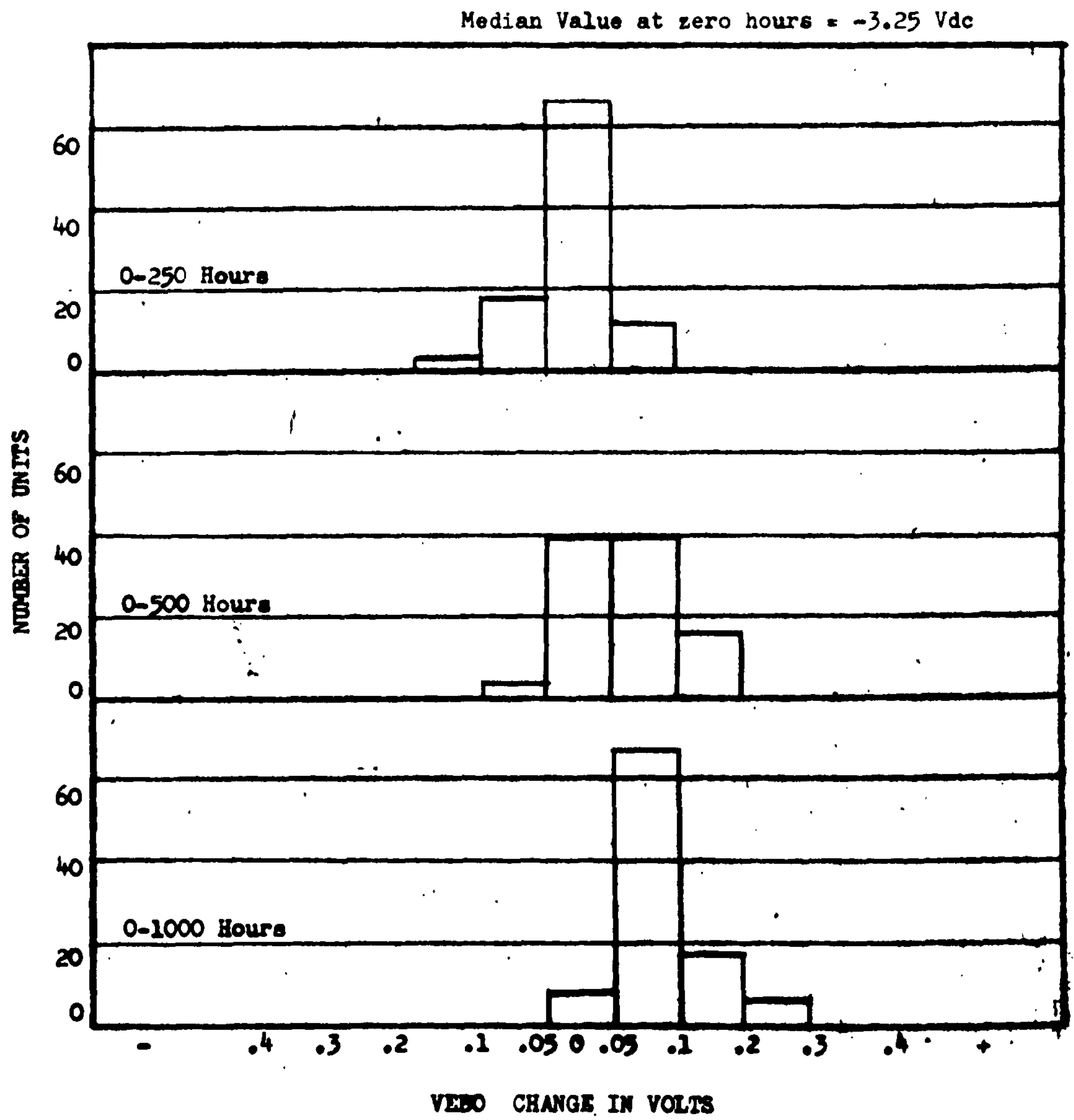
STRESS: STORAGE LIFE - 1000 Hours at 25° C

PARAMETER: VEBO

TEST CONDITIONS: IEB = -50 MA DC

INITIAL LIMIT: -1.5 Vdc Min.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

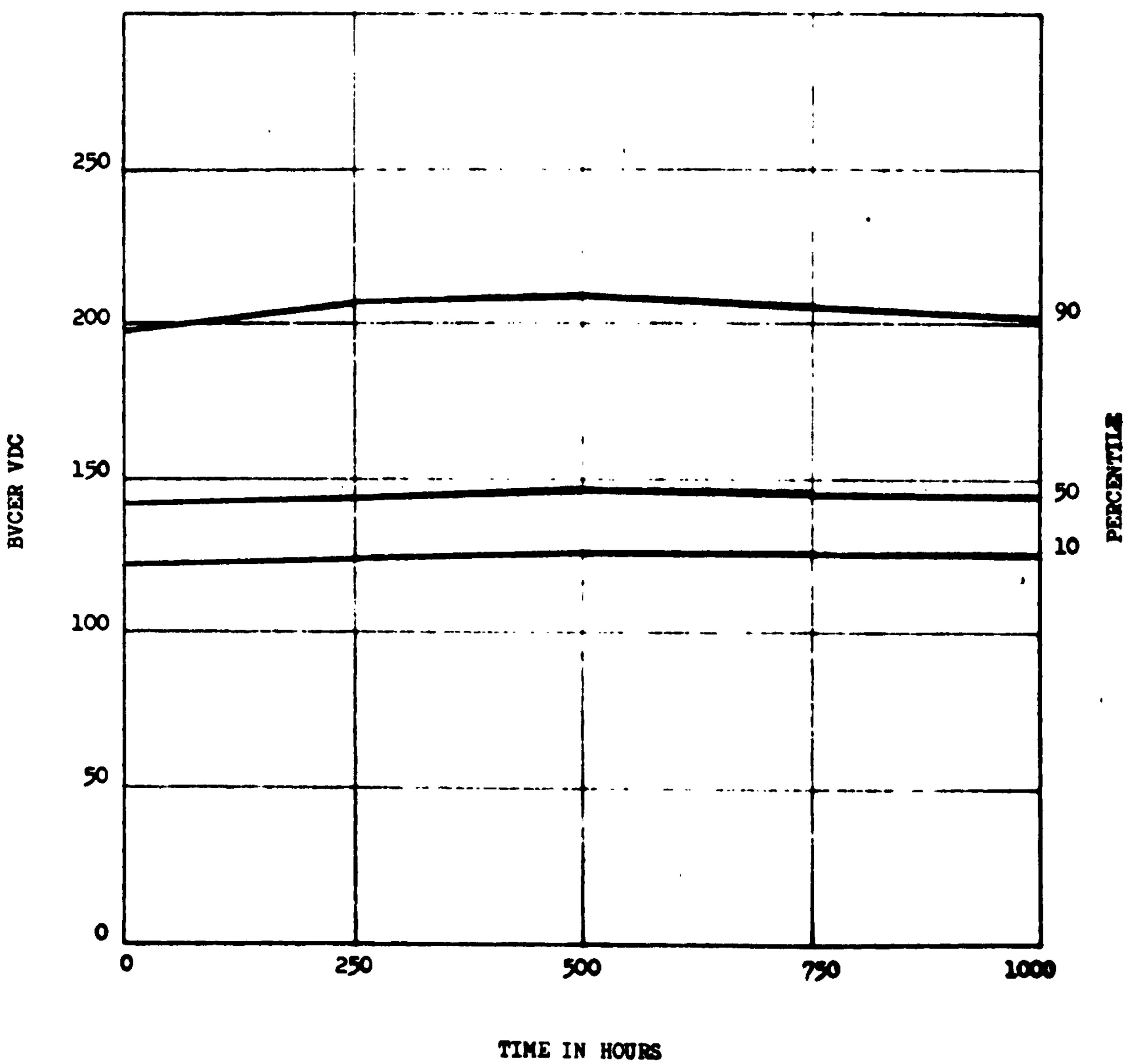
STRESS: STORAGE LIFE - 1000 Hours at 25° C

PARAMETER: BVCER

TEST CONDITIONS: IC = -50 MA DC RBE = 100 Ω

INITIAL LIMIT: -80Vdc Min.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

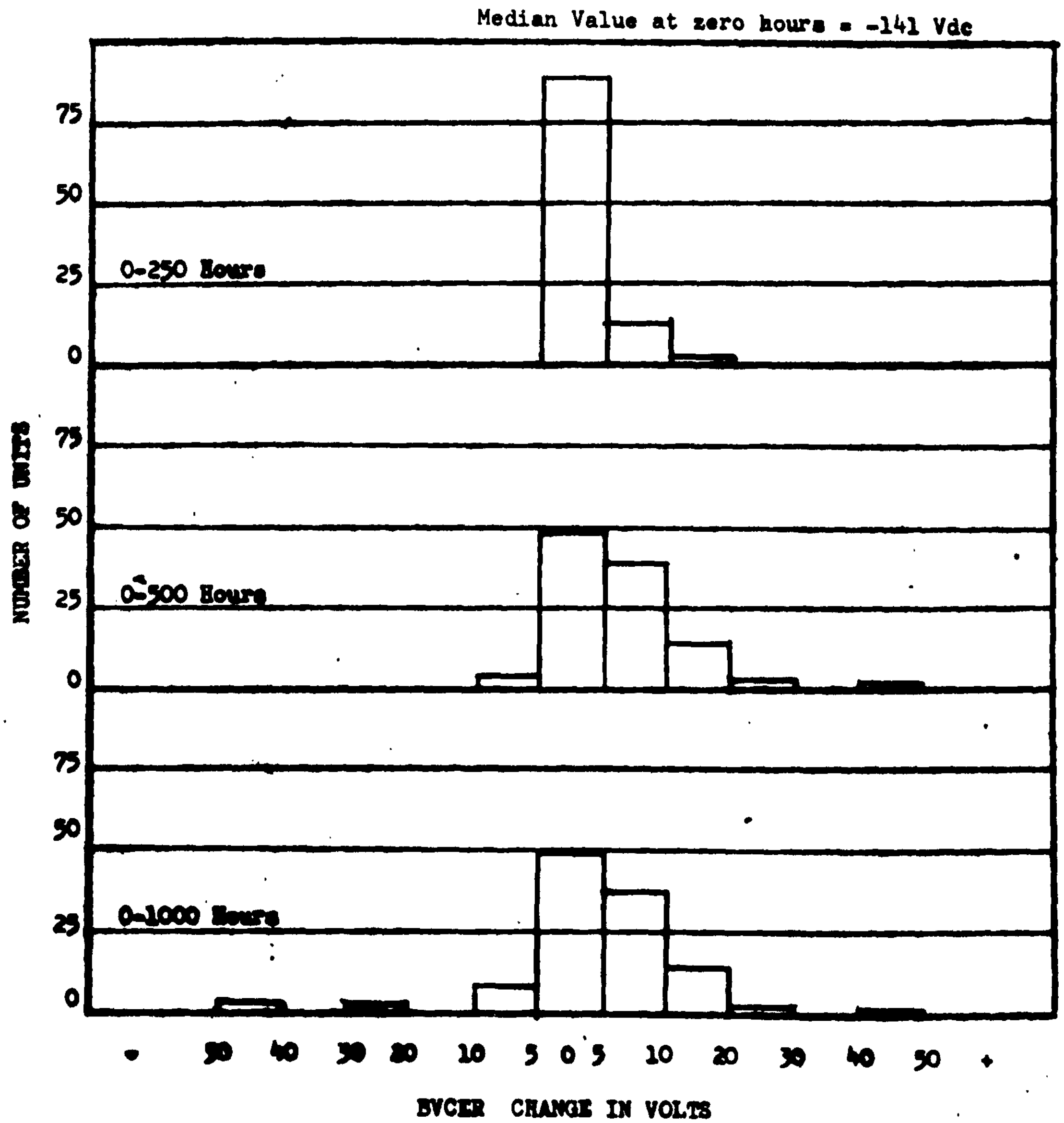
STRESS: 25°C STORAGE LIFE

PARAMETER: BVCER

TEST CONDITIONS: IC = 50 MA DC, RBE = 100Ω

INITIAL LIMIT: -80 Vdc

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION

TRANSISTOR TYPE 2N1430

APPENDIX II

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

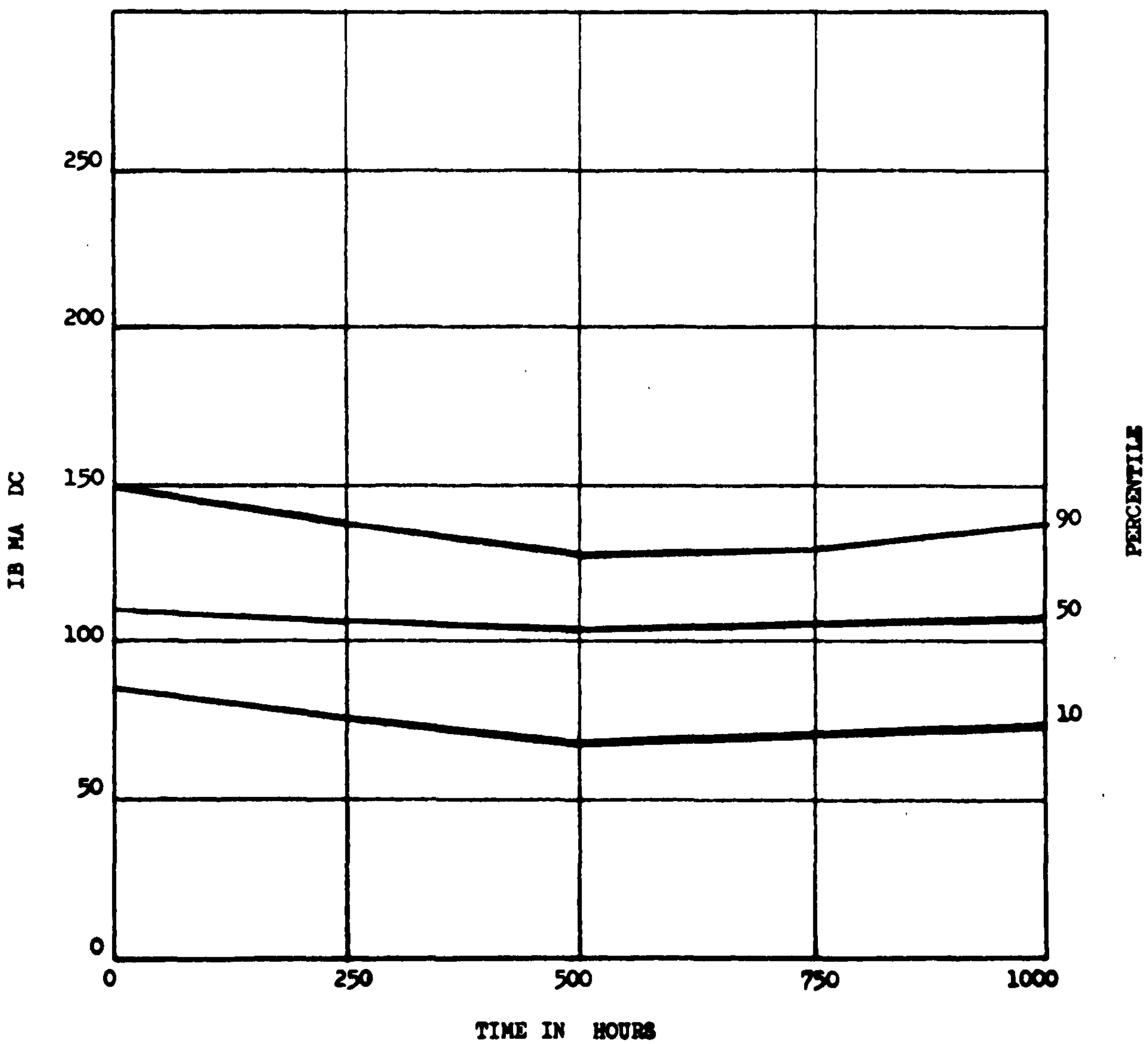
STRESS: STORAGE LIFE - 1000 Hours at 25° C

PARAMETER: IB (h_{FE})

TEST CONDITIONS: VCE = -2Vdc IC = -5Adc

INITIAL LIMIT: -50 MA DC Min. -165 MA DC Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

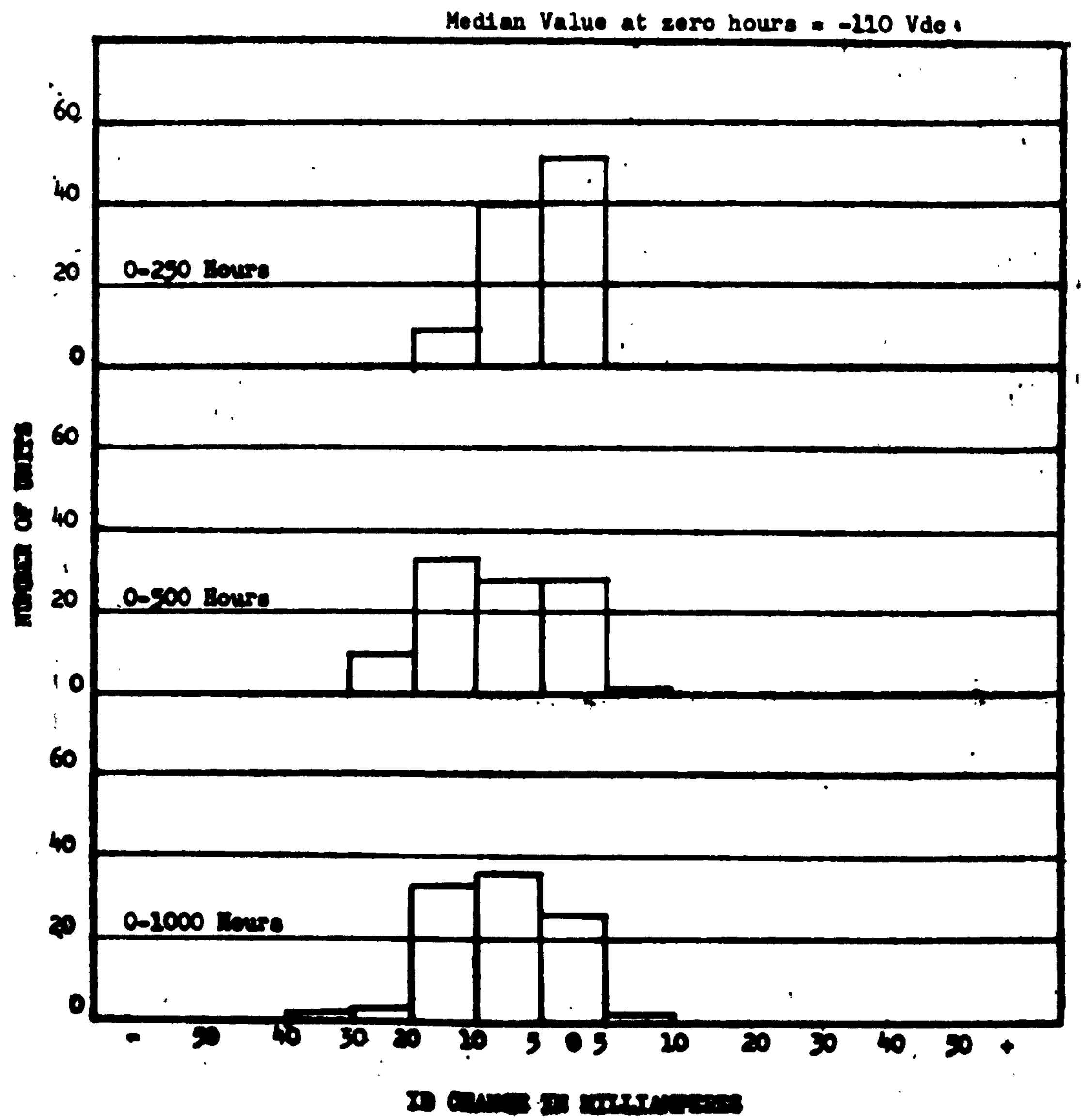
STRESS: 25° C STORAGE LIFE

PARAMETER: IB (h_{FE})

TEST CONDITIONS: Ic = -5.0 MA DC, Vce = -2Vdc

INITIAL LIMIT: -50 MA Min. - 165 MA Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

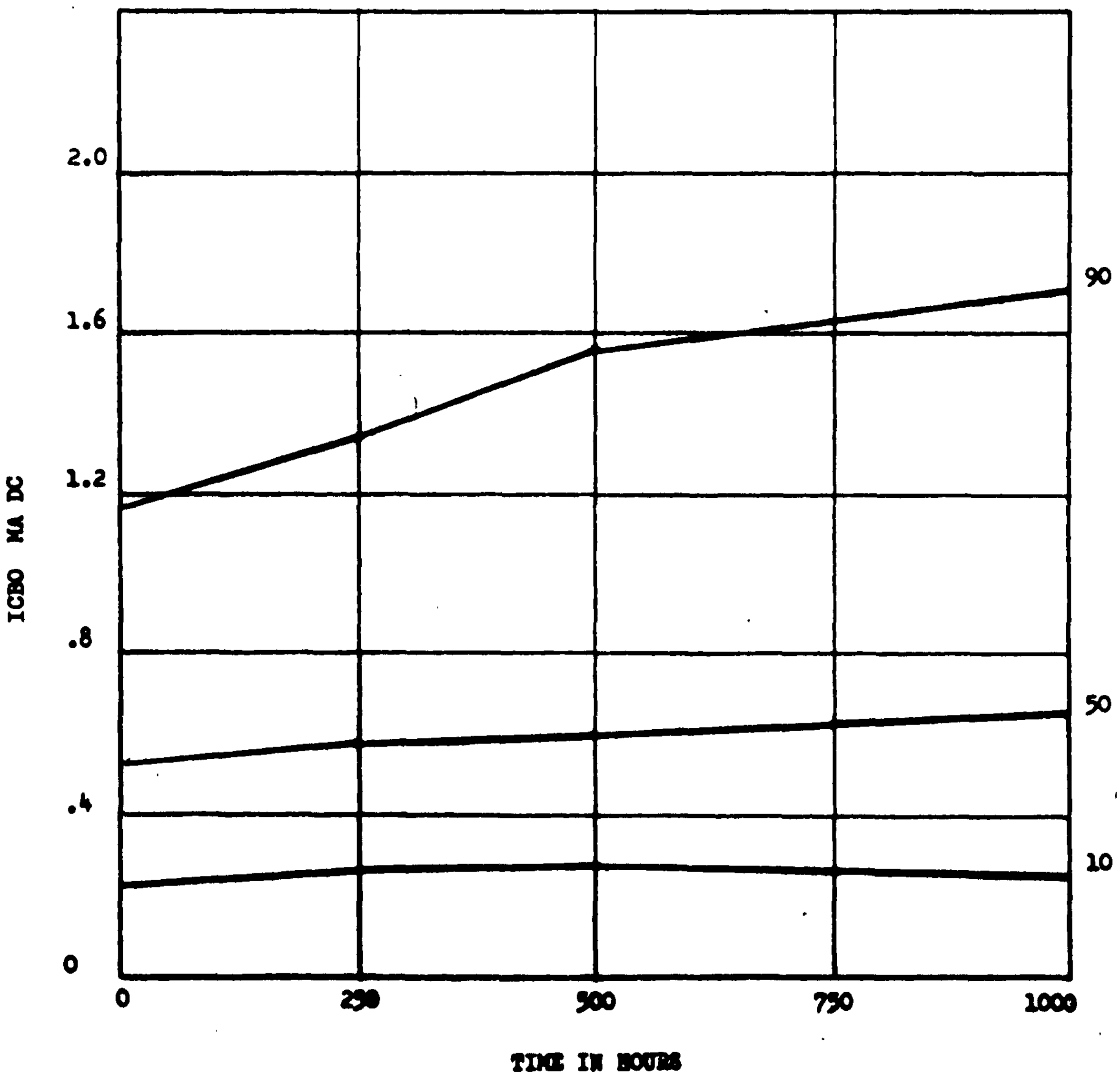
STRESS: STORAGE LIFE - 1000 Hours at 110° C

PARAMETER: ICBO

TEST CONDITIONS: VCB = -100Vdc

INITIAL LIMIT: -50mA dc Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

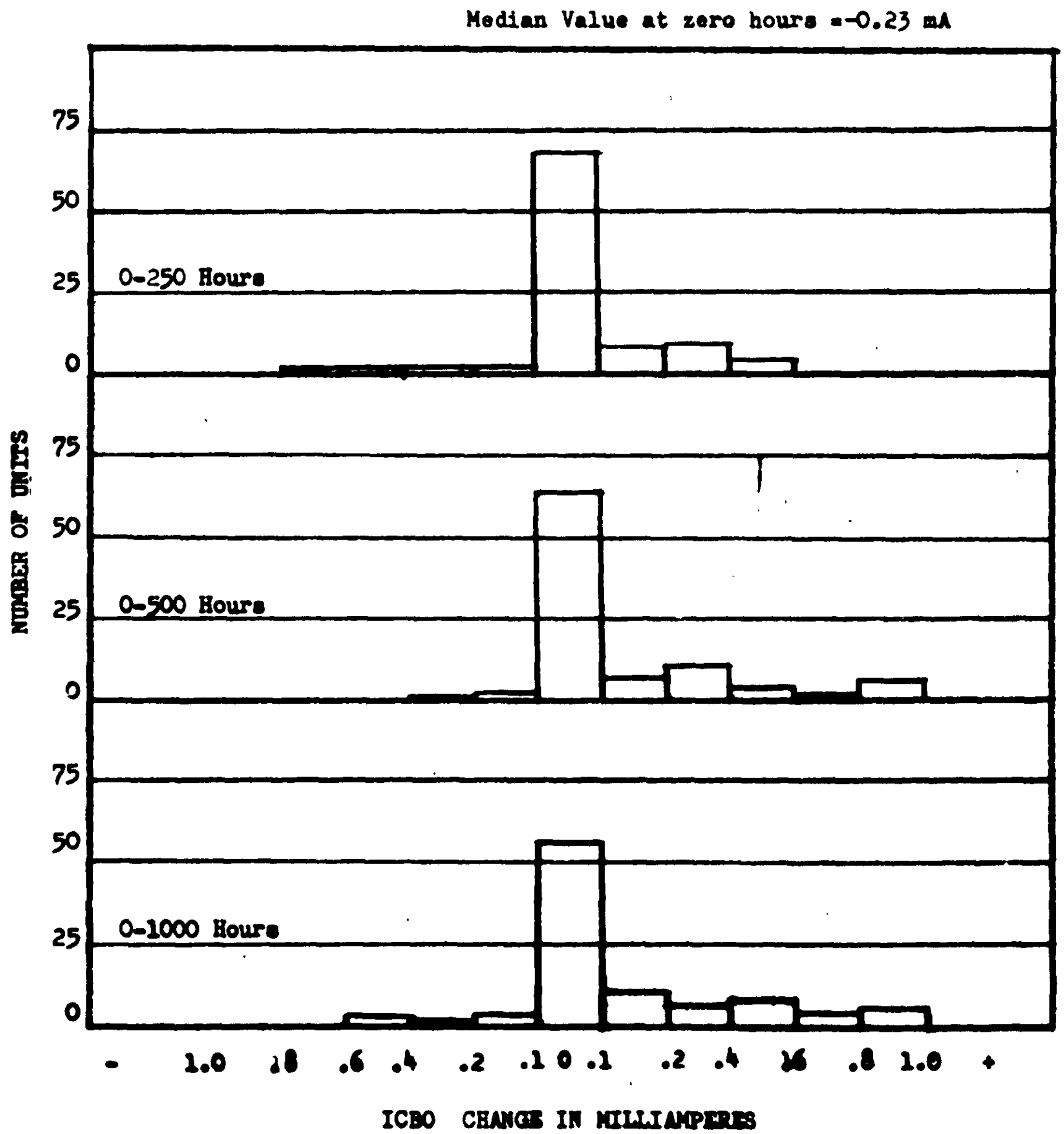
STRESS: 110° C STORAGE LIFE

PARAMETER: ICBO

TEST CONDITIONS: VCB = -100 Vdc, IE = 0

INITIAL LIMIT: -50 mAdc Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

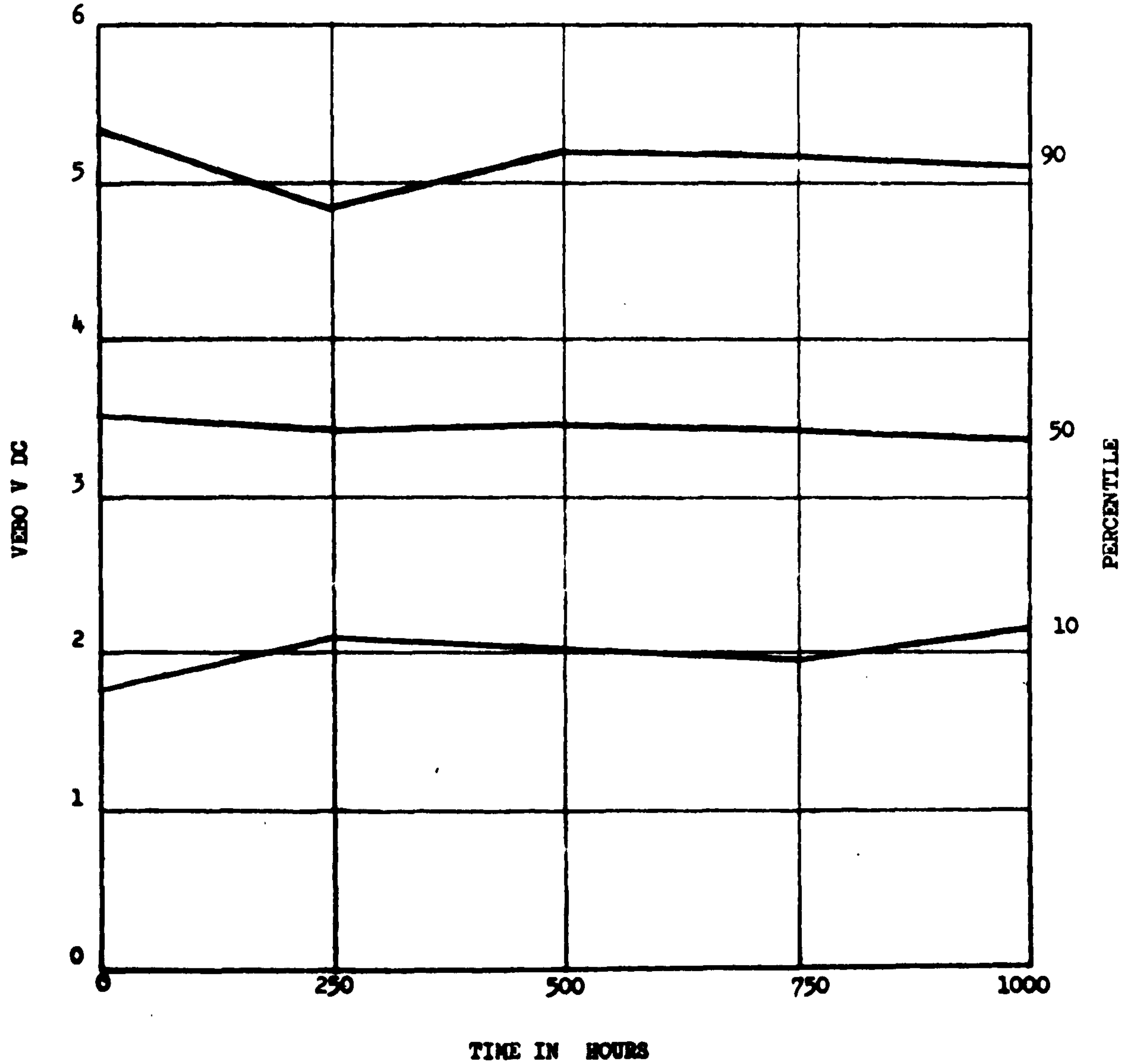
STRESS: STORAGE LIFE - 1000 Hours at 110° C

PARAMETER: VEBO

TEST CONDITIONS: IEB = -50 MA DC

INITIAL LIMIT: -1.5 Vdc Min.

NUMBER OF UNITS: 100



APPENDIX II

THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

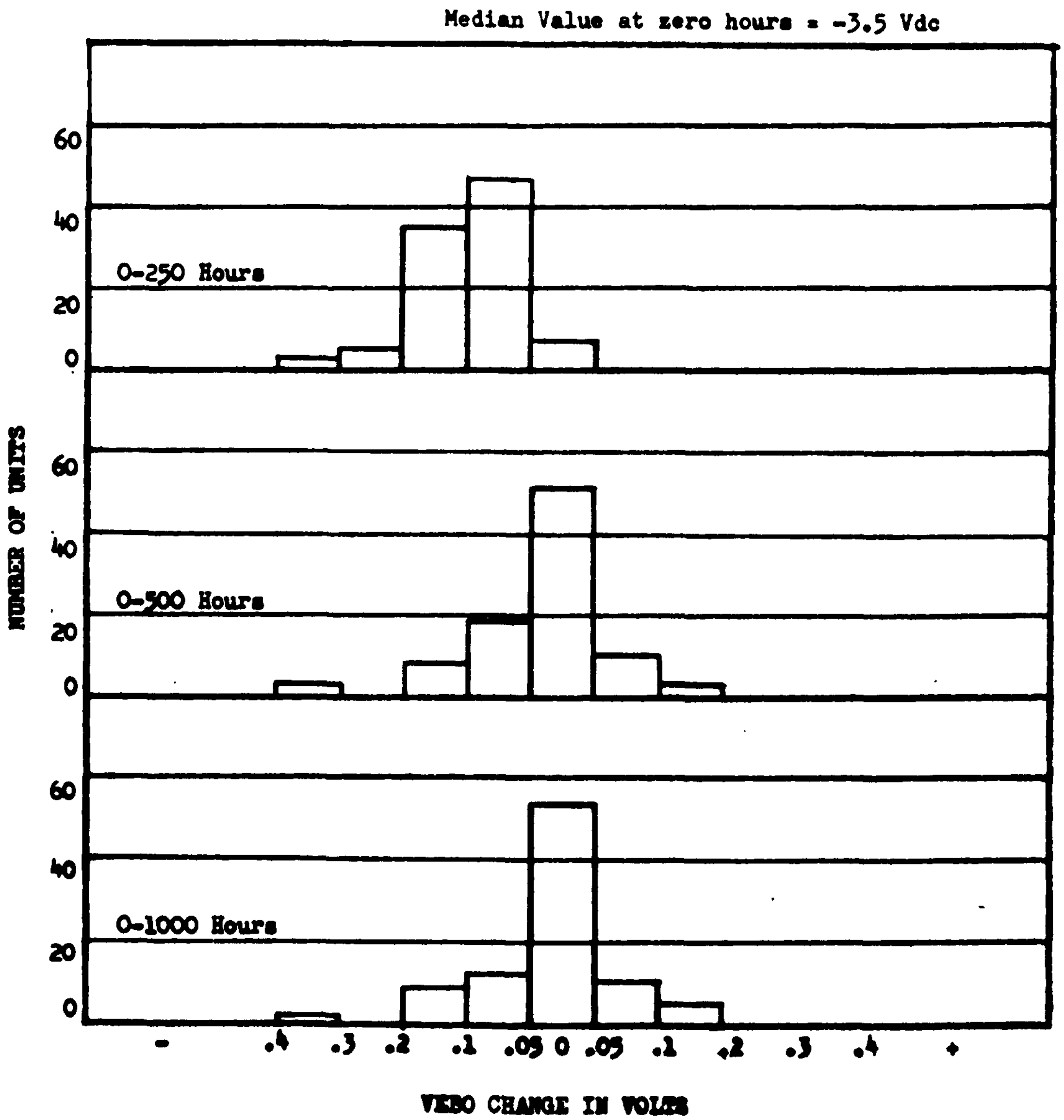
STRESS: STORAGE LIFE - 1000 Hours at 110° C

PARAMETER: VEBO

TEST CONDITIONS: IEB = -50 MA DC

INITIAL LIMIT: -1.5 Vdc Min.

NUMBER OF UNITS: 100



APPENDIX II

THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION

TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

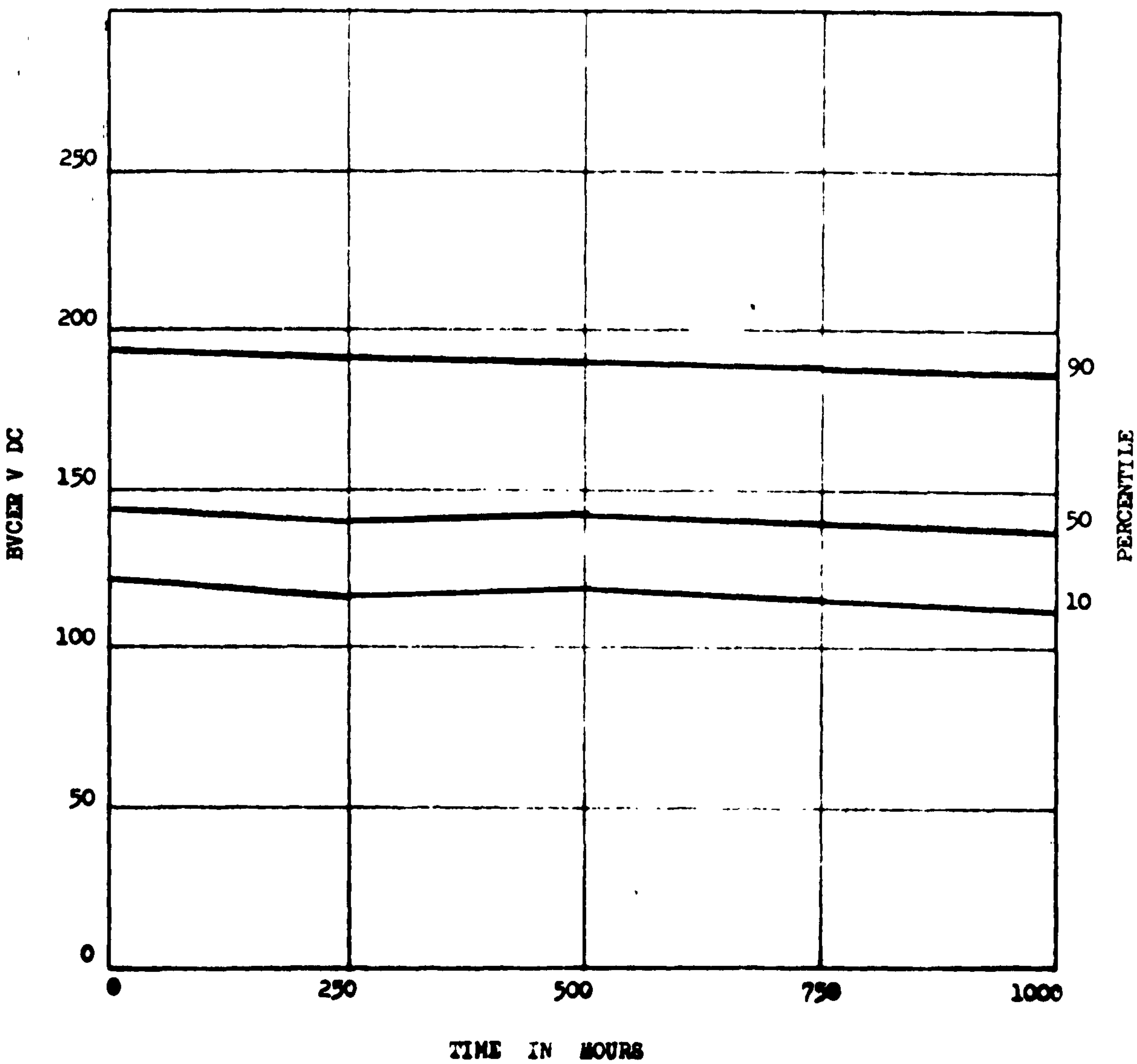
STRESS: STORAGE LIFE - 1000 at 110° C

PARAMETER: BVCER

TEST CONDITIONS: IC = -50 MA DC RBE = 100Ω

INITIAL LIMIT: - 80Vdc Min.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

STRESS: 110° C STORAGE LIFE

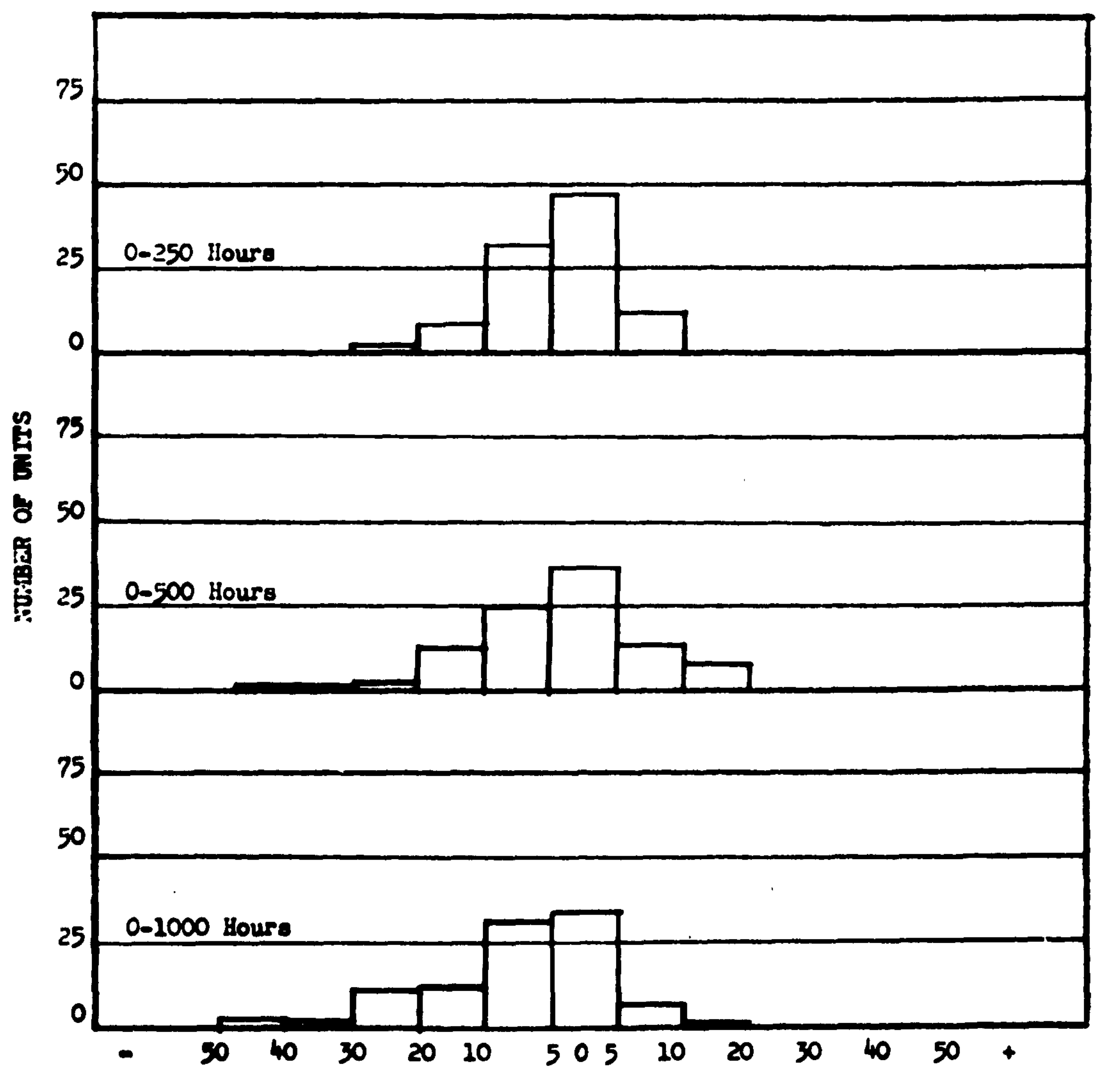
PARAMETER: BVCER

TEST CONDITIONS: IC = -50 MA DC, RBE = 100Ω

INITIAL LIMIT: -80 Vdc Min.

NUMBER OF UNITS: 100

Median Value at zero hours = -144 Vdc



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION

TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere

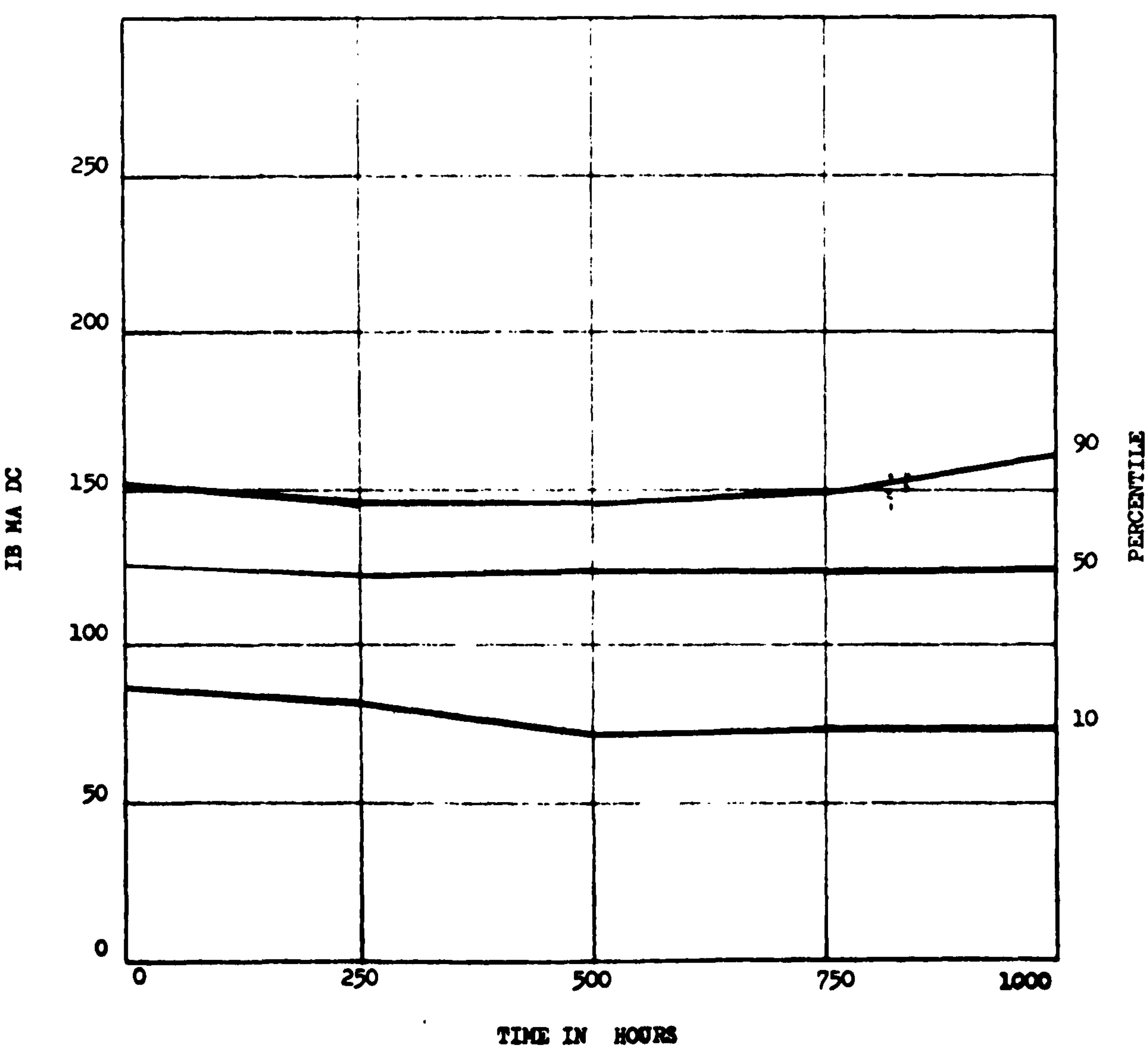
STRESS: STORAGE LIFE - 1000 at 110° C

PARAMETER: IB (h_{FE})

TEST CONDITIONS: VCE = -2Vdc IC = -5 Adc

INITIAL LIMIT: .50 MA DC Min. 165 MA DC Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

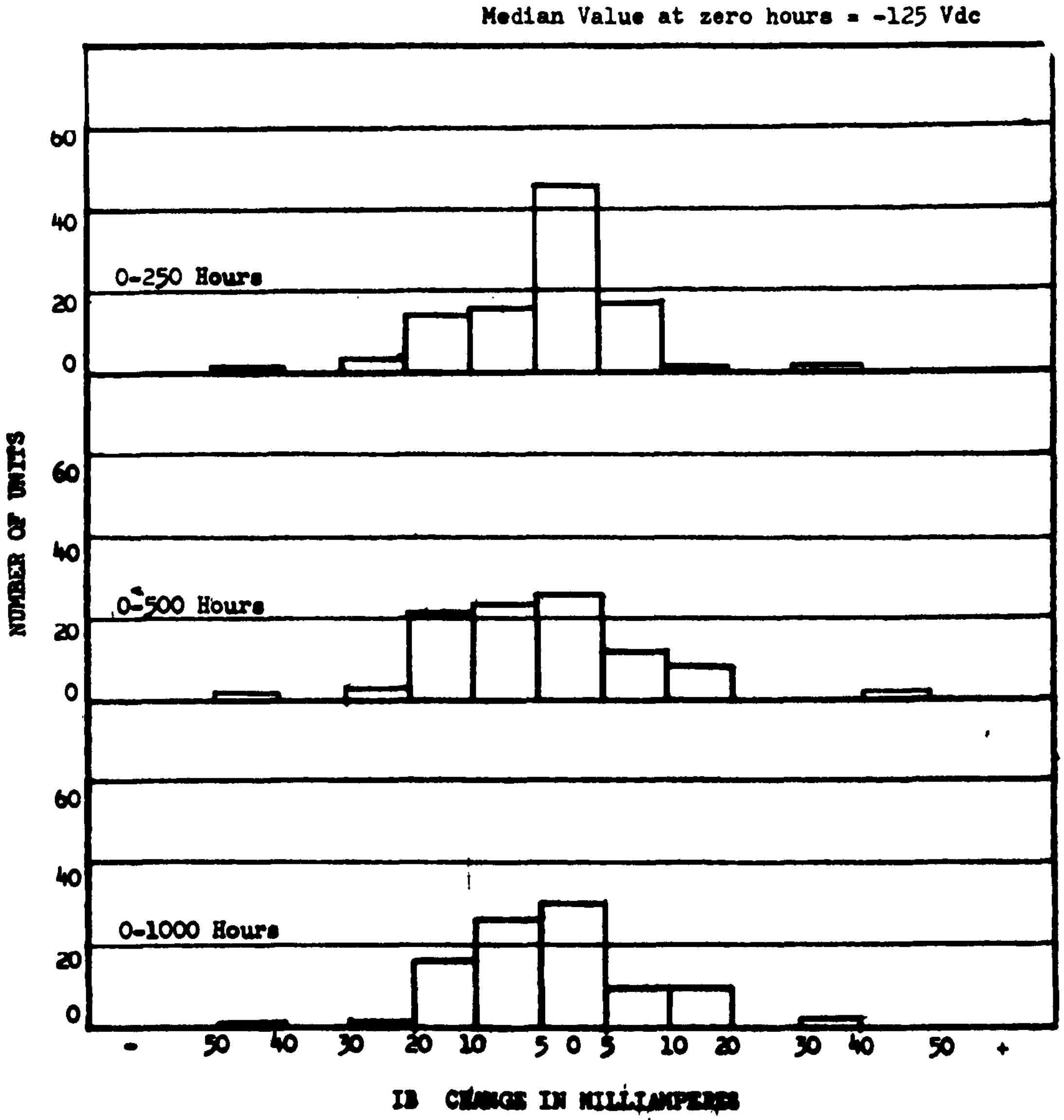
STRESS: 110° C STORAGE LIFE

PARAMETER: IB (h_{FE})

TEST CONDITIONS: IC = 5.0 Adc, VCE = -2Vdc

INITIAL LIMIT: - 50 MA MIN., -165 MA MAX.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

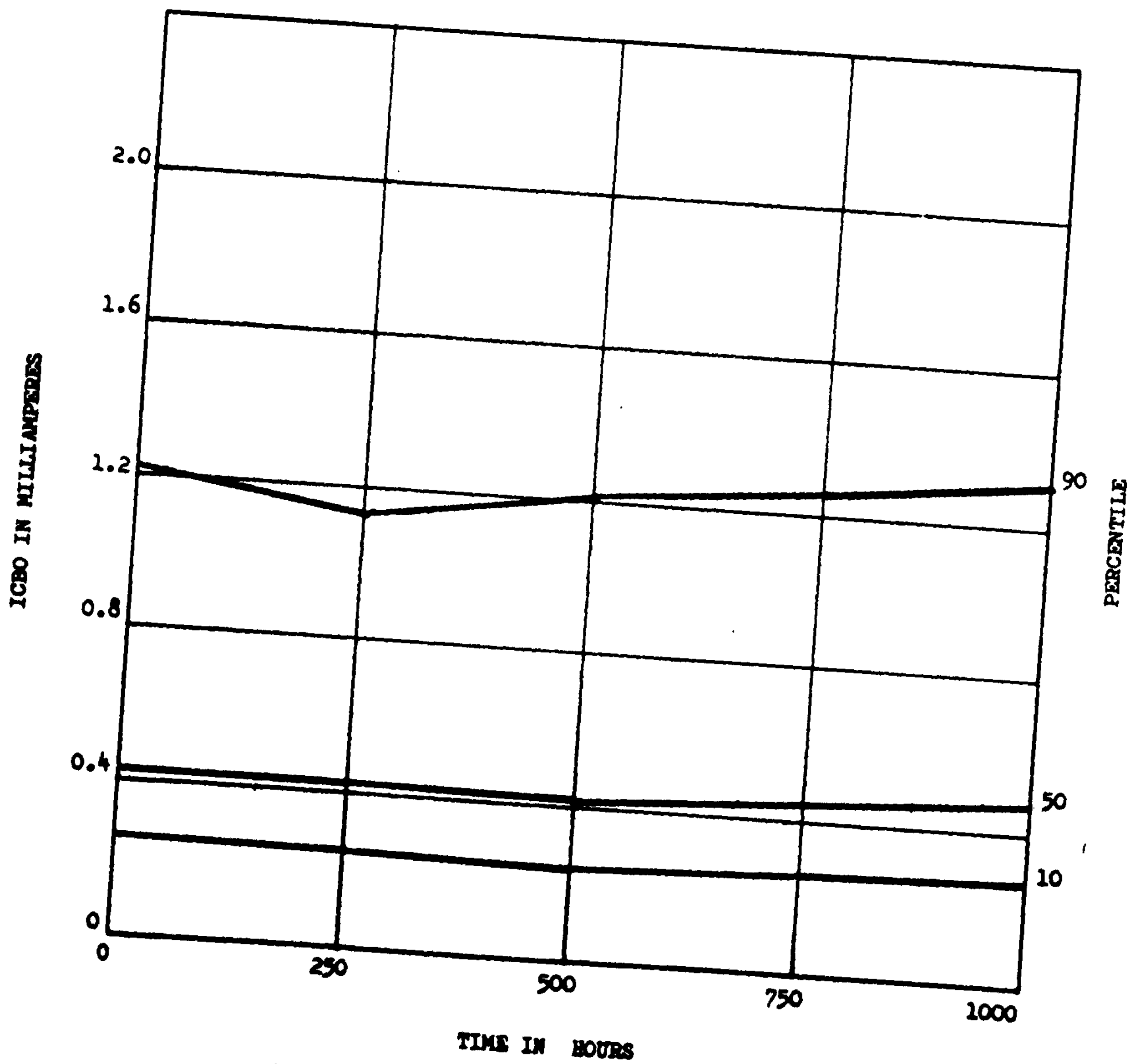
STRESS: OPERATING LIFE - 1000 Hours at 85° C Pc = 30 Watts

PARAMETER: ICBO

TEST CONDITIONS: VCB = -100 Vdc

INITIAL LIMIT: -50 mAdc Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

STRESS: OPERATING LIFE - 1000 Hours at 85° C Pc = 30 Watt

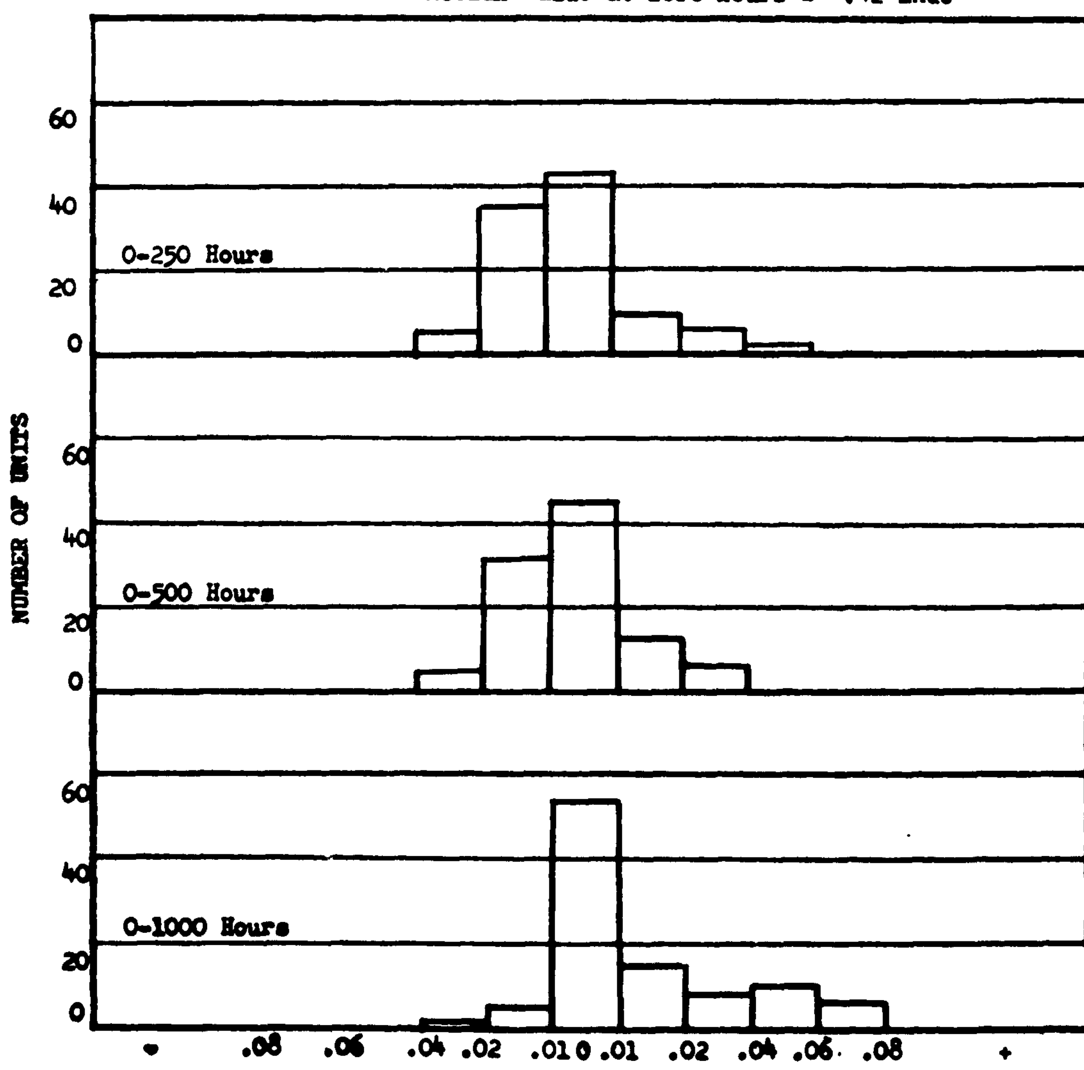
PARAMETER: ICBO

TEST CONDITIONS: VCB = -100 Vdc

INITIAL LIMIT: -50 mAdc Max.

NUMBER OF UNITS: 100

Median Value at zero hours = -.42 mAdc



ICBO CHANGE IN MILLIAMPERES

THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION

TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

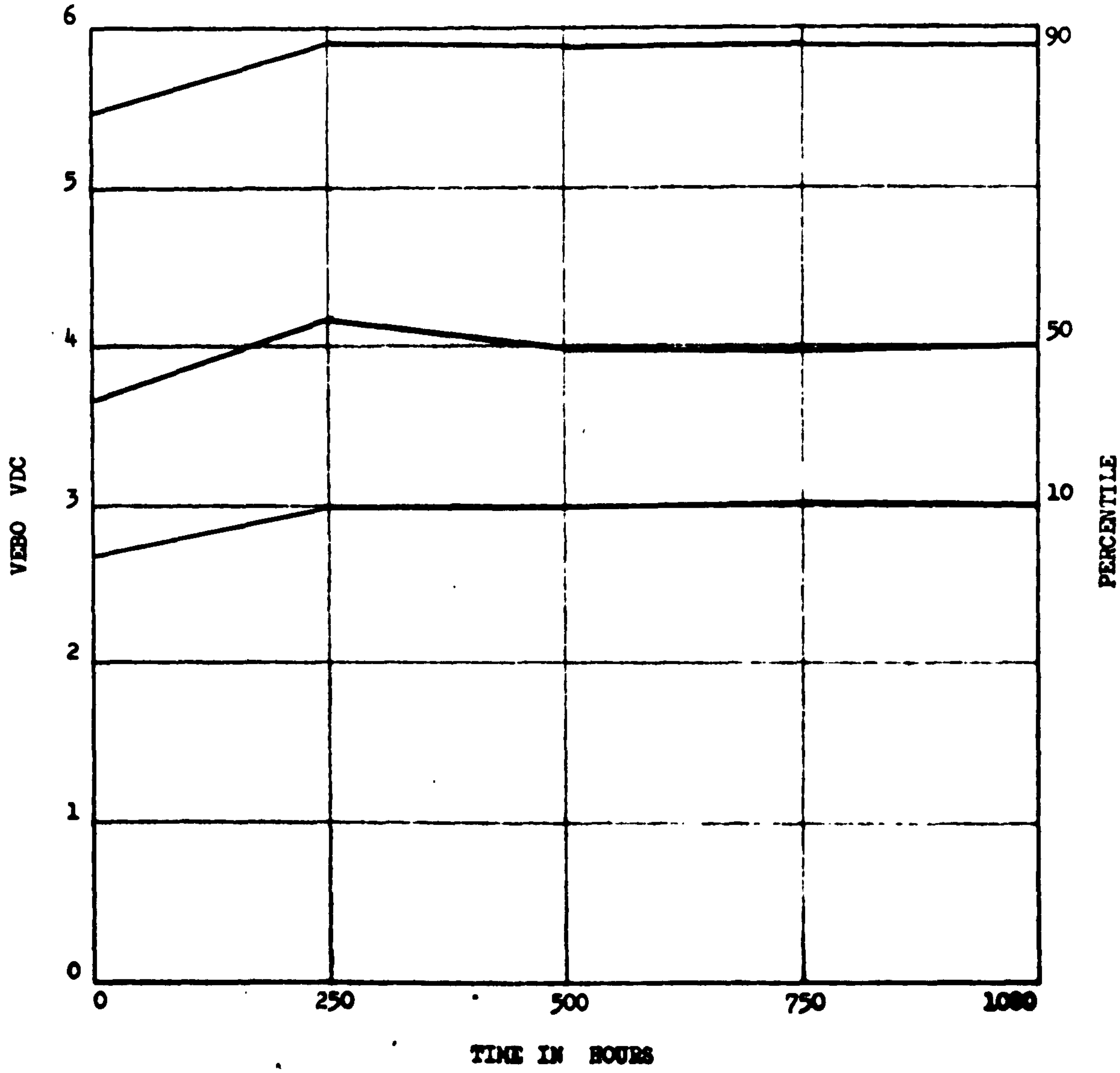
TYPE: 10 Ampere DAP

STRESS: OPERATING LIFE - 1000 Hours at 85° C Pc = 30 Watts

PARAMETER: VEBO

TEST CONDITIONS: IE = -50 MA DC

INITIAL LIMIT: -1.5 Vdc Min.



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

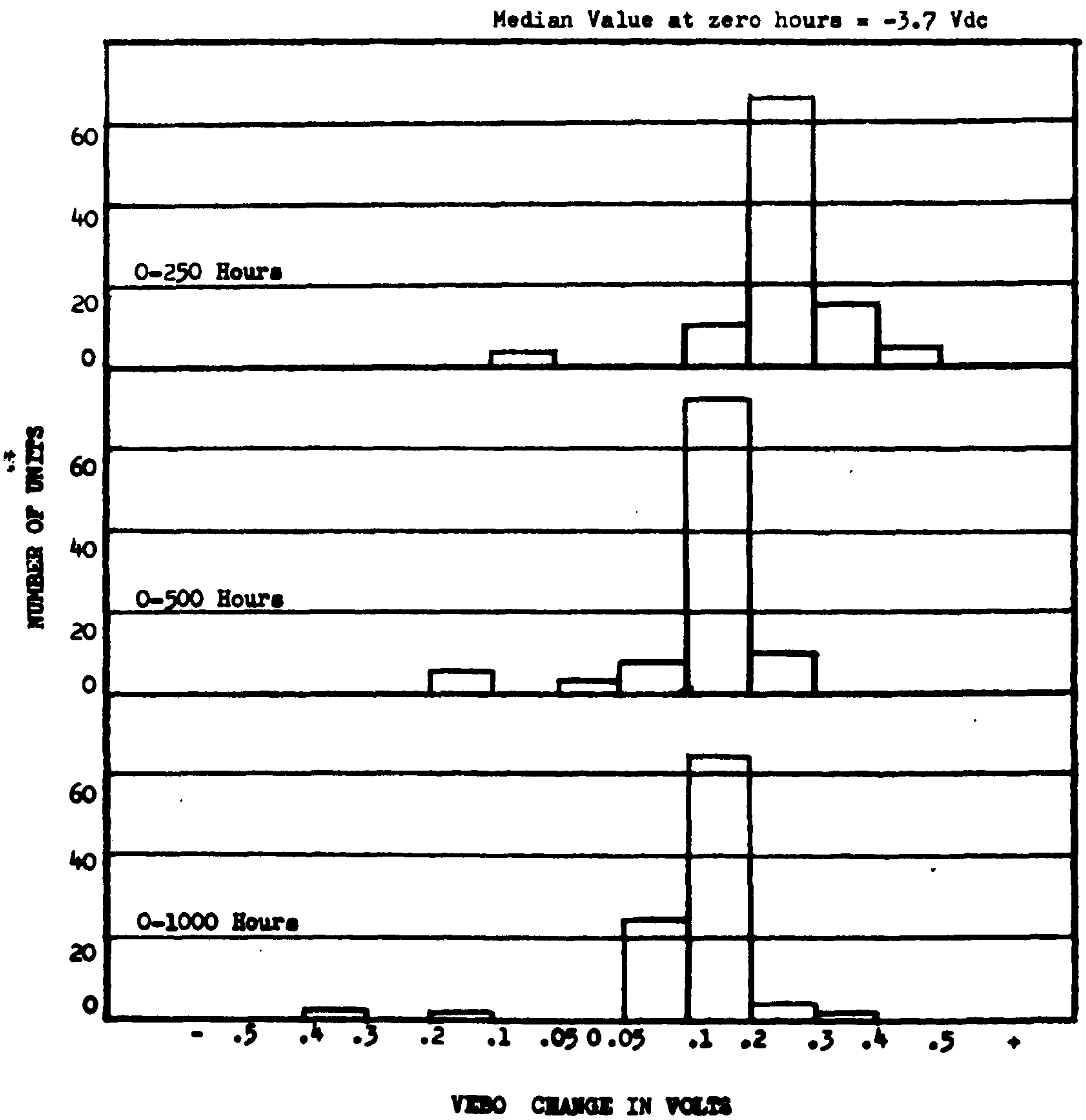
STRESS: OPERATING LIFE - 1000 Hours at 85° C Pc = 30 Watts

PARAMETER: VEBO

TEST CONDITIONS: IE = -50 MA DC

INITIAL LIMIT: -1.5 Vdc Min.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

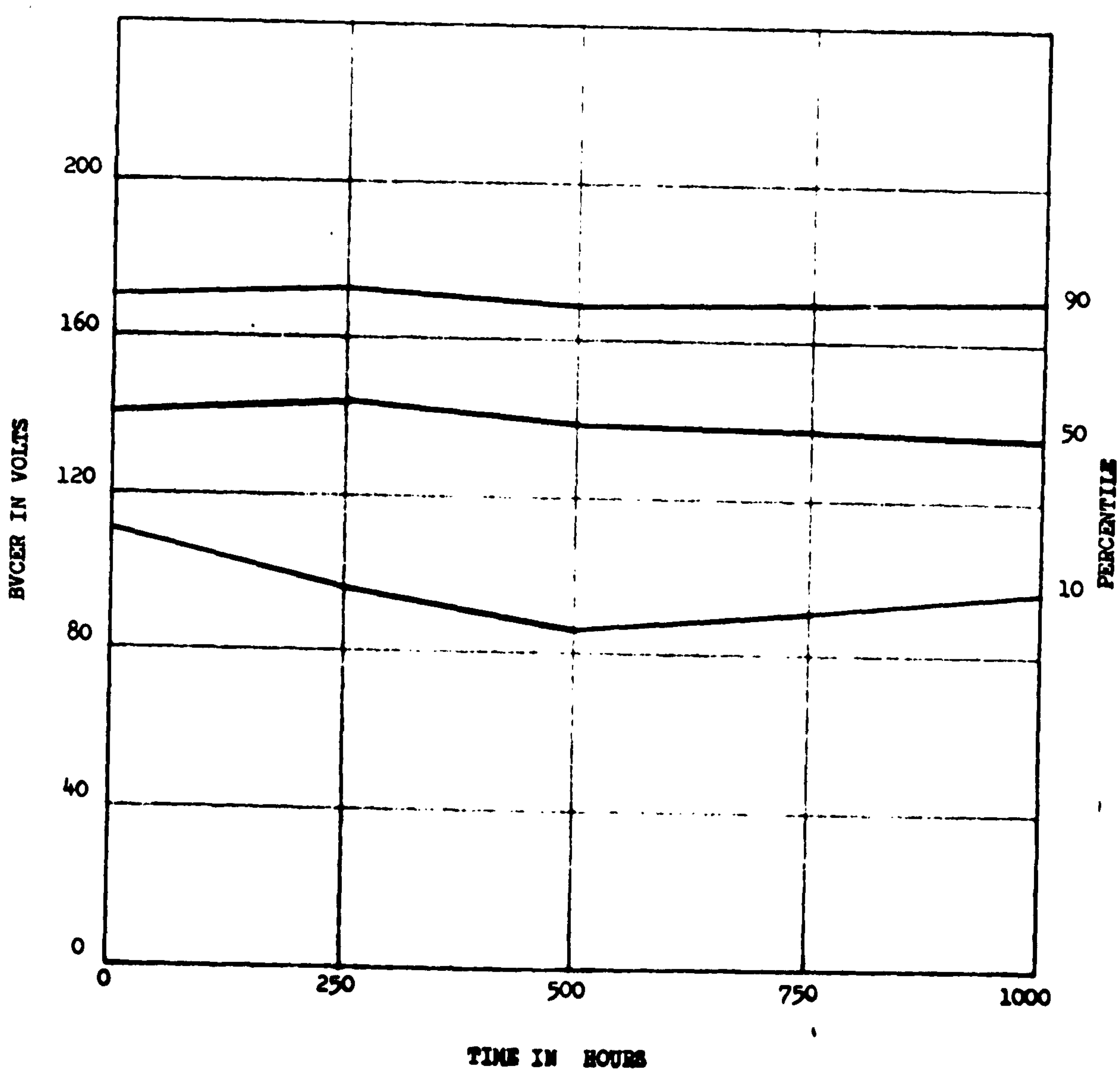
STRESS: OPERATING LIFE 1000 Hours at 85° C Pc = 30 Watts

PARAMETER: BVCER

TEST CONDITIONS: IC = -50 MA DC RBE = 100Ω

INITIAL LIMIT: -80 Vdc Min.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

STRESS: OPERATING LIFE - 1000 Hours at 85° C Pc = 30 W

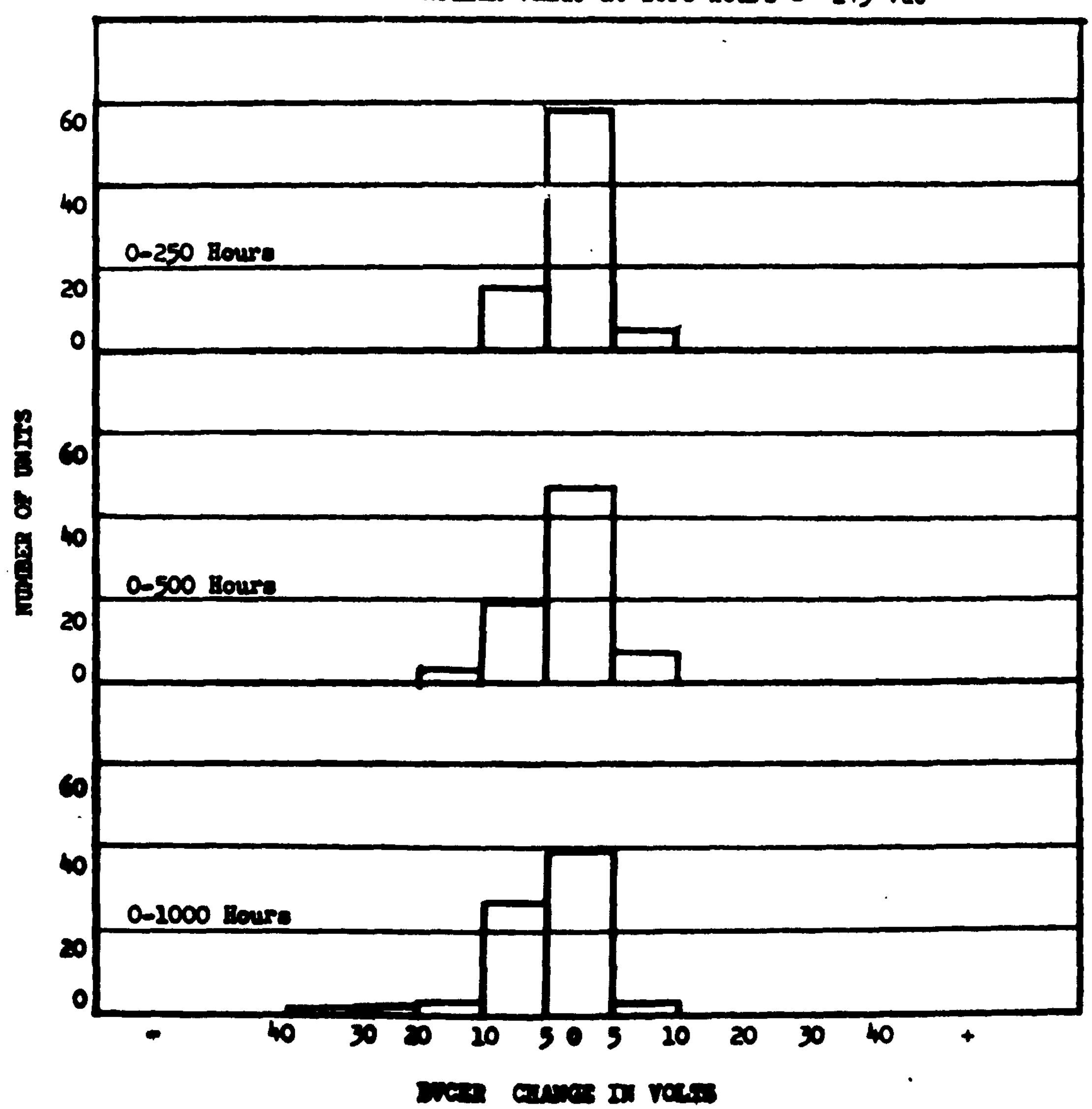
PARAMETER: BVCER

TEST CONDITIONS: IC = -50 MA DC RBE = 100Ω

INITIAL LIMIT: -80 Vdc Min.

NUMBER OF UNITS: 100

Median Value at zero hours = -145 Vdc



PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

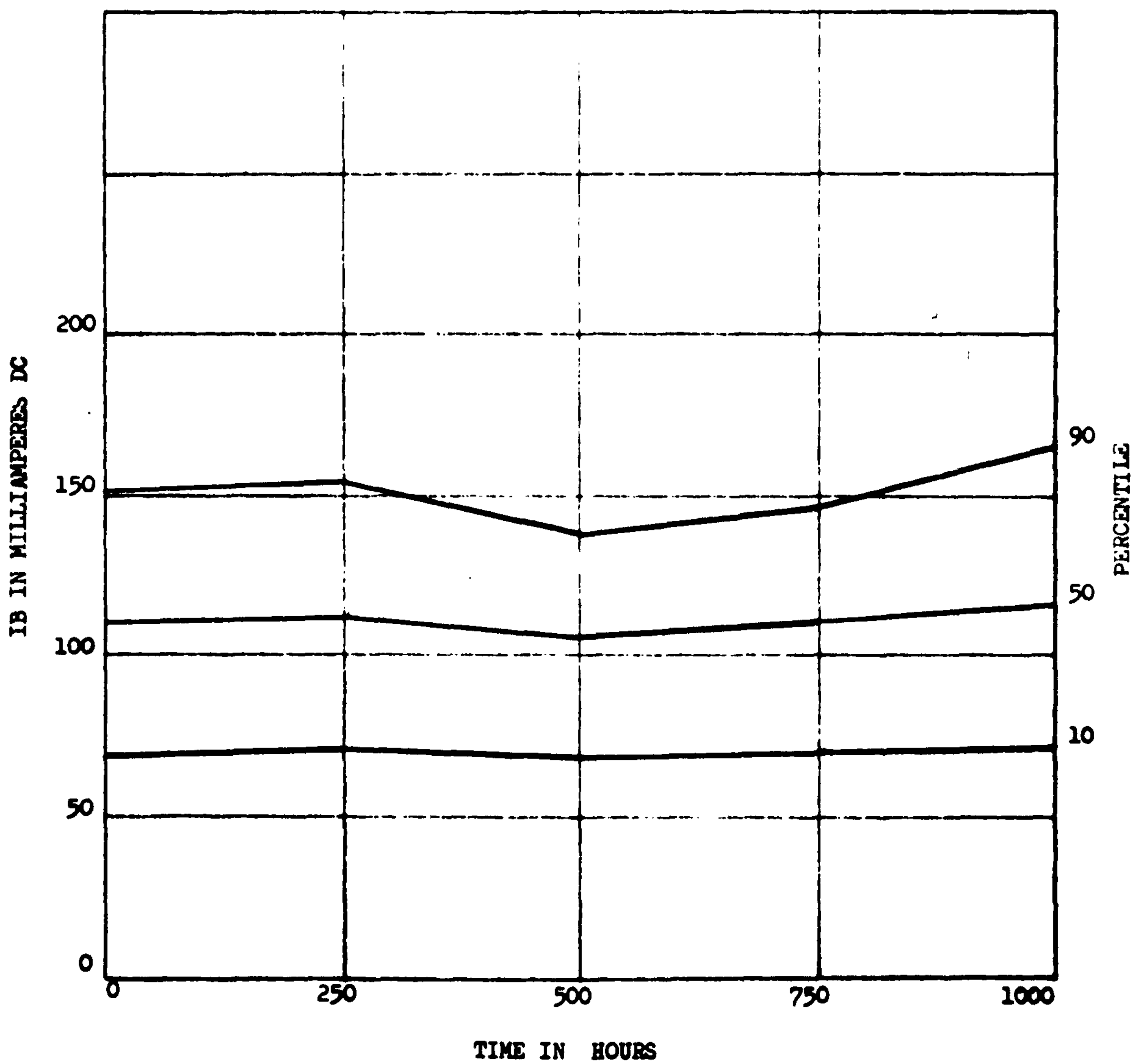
STRESS: OPERATING LIFE - 1000 Hours at 85° C Pc = 30 Watts

PARAMETER: IB (h_{FE})

TEST CONDITIONS: IC = -5A DC VCE = -2V DC

INITIAL LIMITS: -50 MA DC Min. -165 MA DC Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER STABILITY

STRESS: OPERATING LIFE 1000 Hours at 85° C Pc = 30 Watts

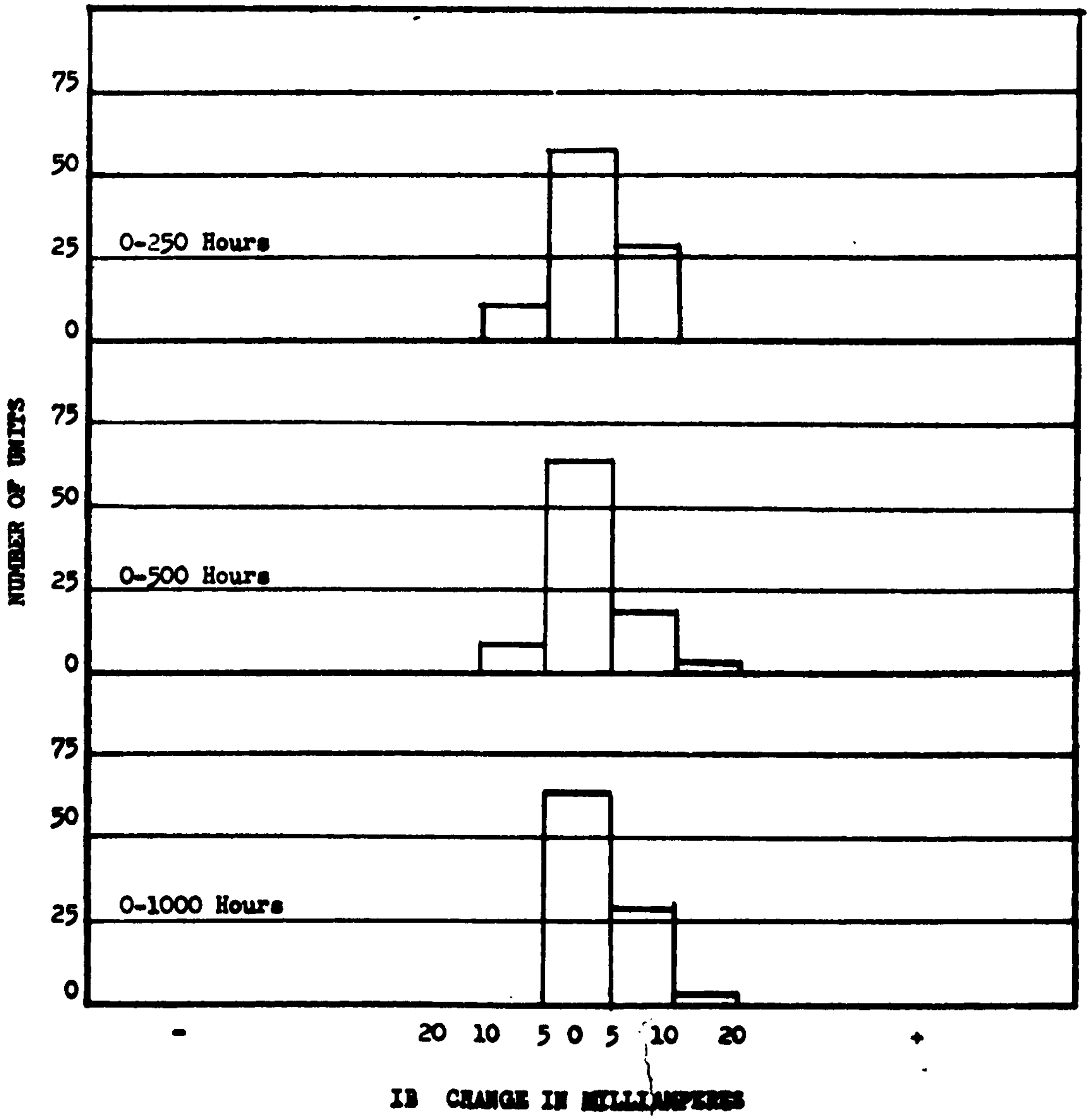
PARAMETER: IB

TEST CONDITIONS: IC = -5 A DC VCE = -2Vdc

INITIAL LIMIT: -50 MA DC Min. -165 MA DC Max.

NUMBER OF UNITS: 100

Median Value at zero hours = -110 Vdc



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

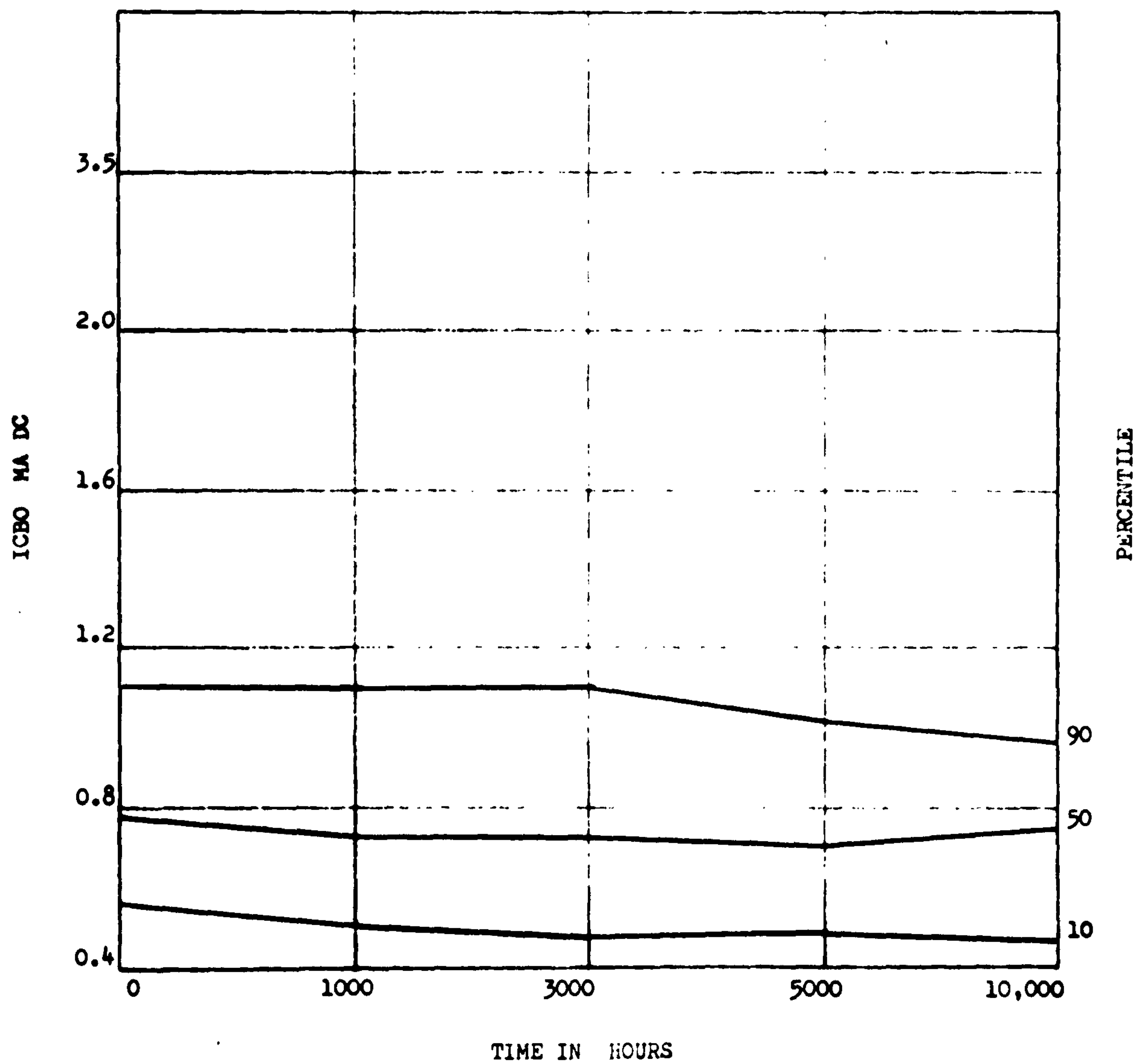
STRESS: STORAGE LIFE - 10,000 Hours at 25° C

PARAMETER: ICBO

TEST CONDITIONS: VCB = -100 Vdc

INITIAL LIMIT: -50 mAdc Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

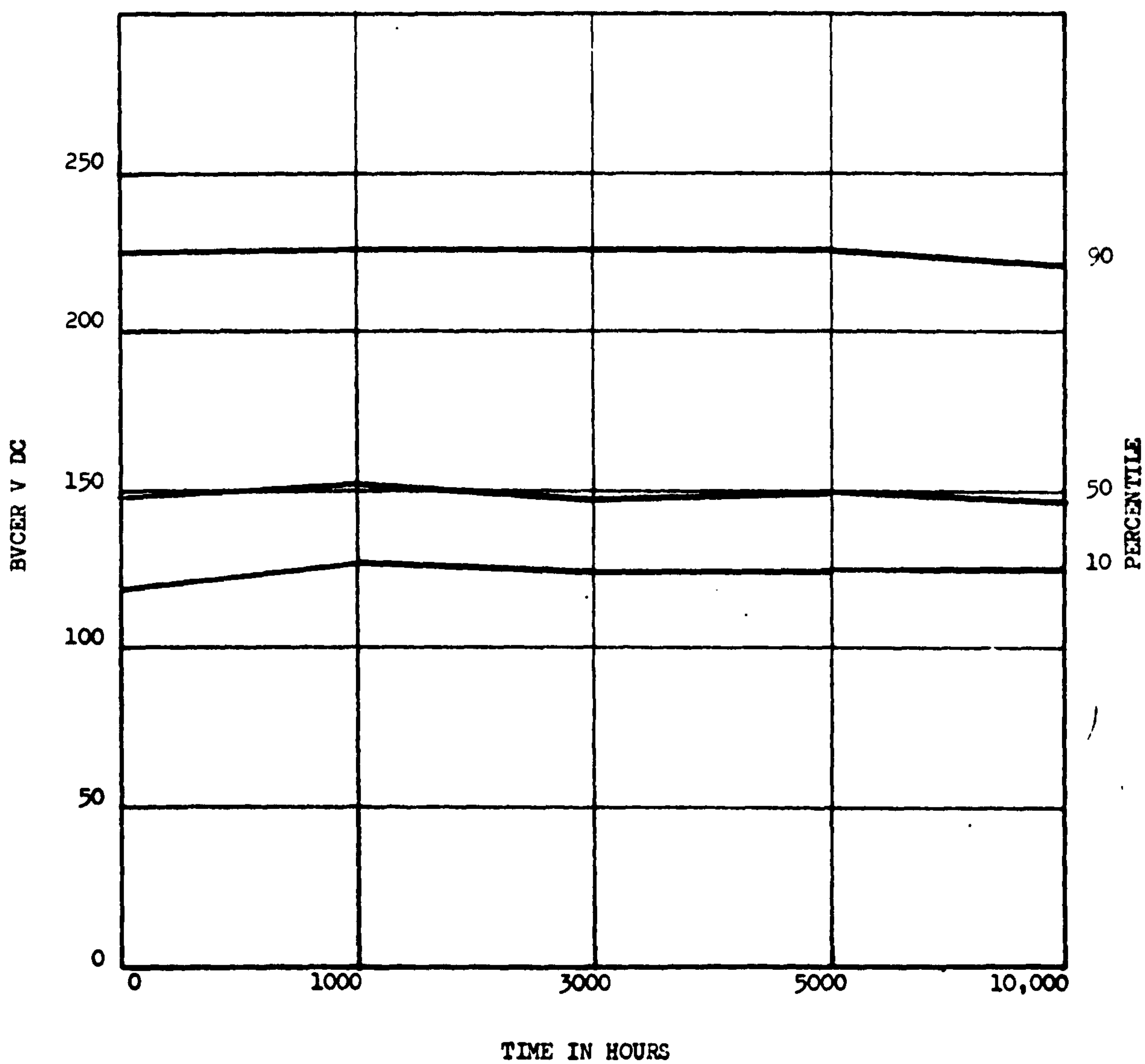
STRESS: STORAGE LIFE - 10,000 Hours at 25° C

PARAMETER: BVCER

TEST CONDITIONS: IC = -50 MA DC RBE = 100Ω

INITIAL LIMIT: -80 Vdc Min.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

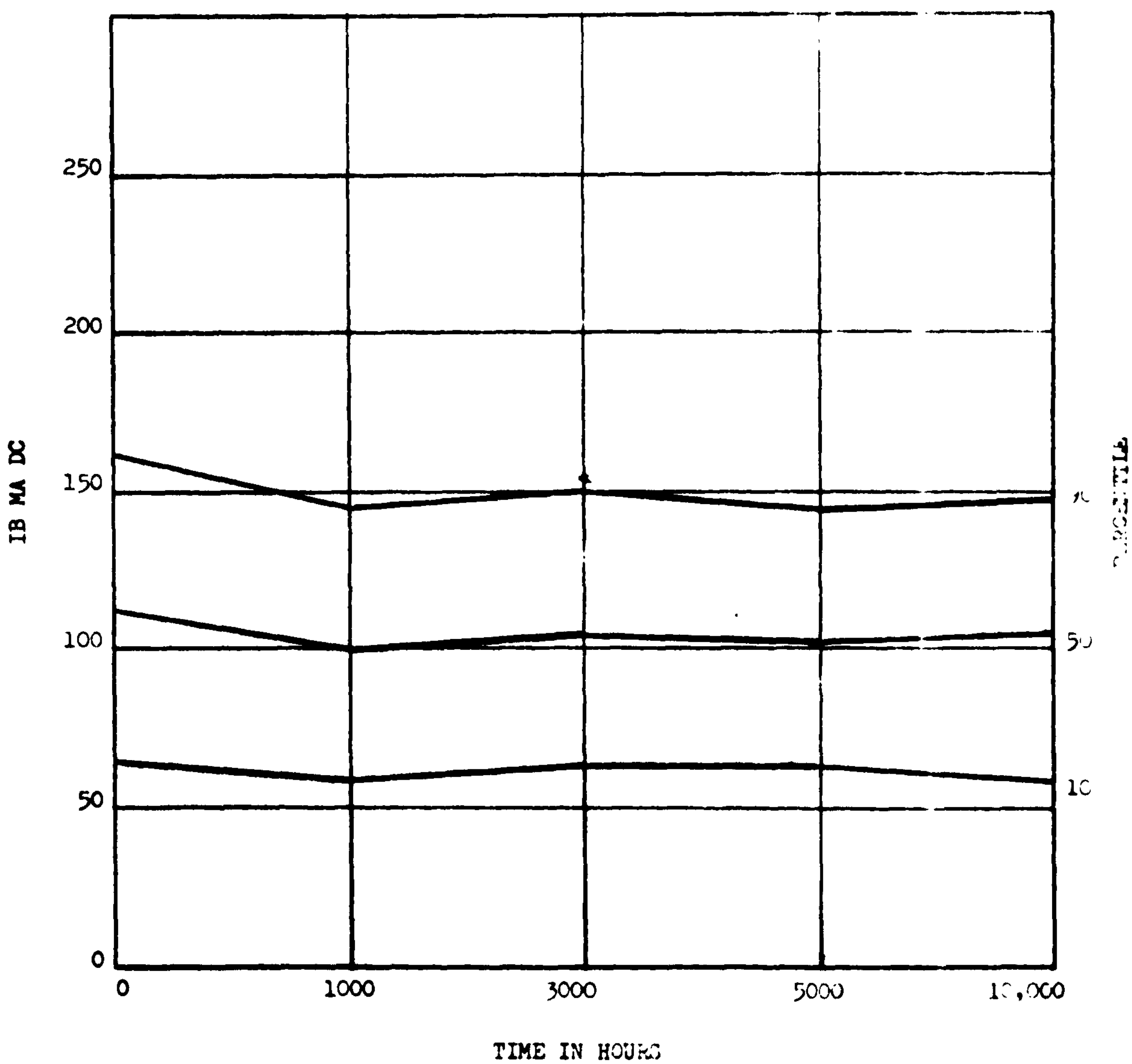
STRESS: STORAGE LIFE - 10,000 at 25° C

PARAMETER: IB (h_{FE})

TEST CONDITIONS: VCE = -2Vdc IC = -5 Adc

INITIAL LIMIT: -50 MA DC Min. -165 MA DC Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION

TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

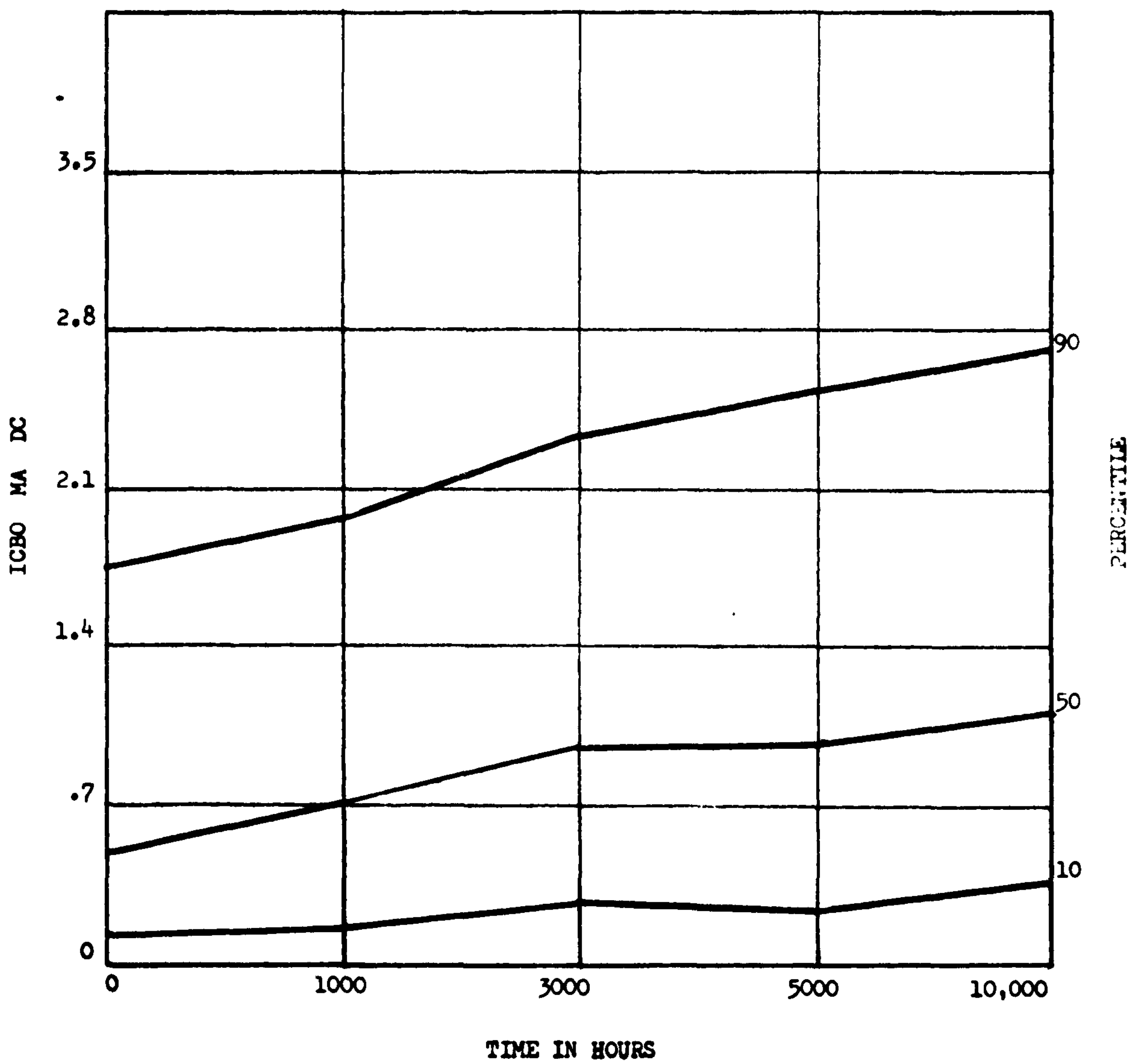
STRESS: STORAGE LIFE - 10,000 Hours at 110° C

PARAMETER: ICBO

TEST CONDITIONS: VCB = -100 MA DC

INITIAL LIMIT: -50 mAdc Max.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION
TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

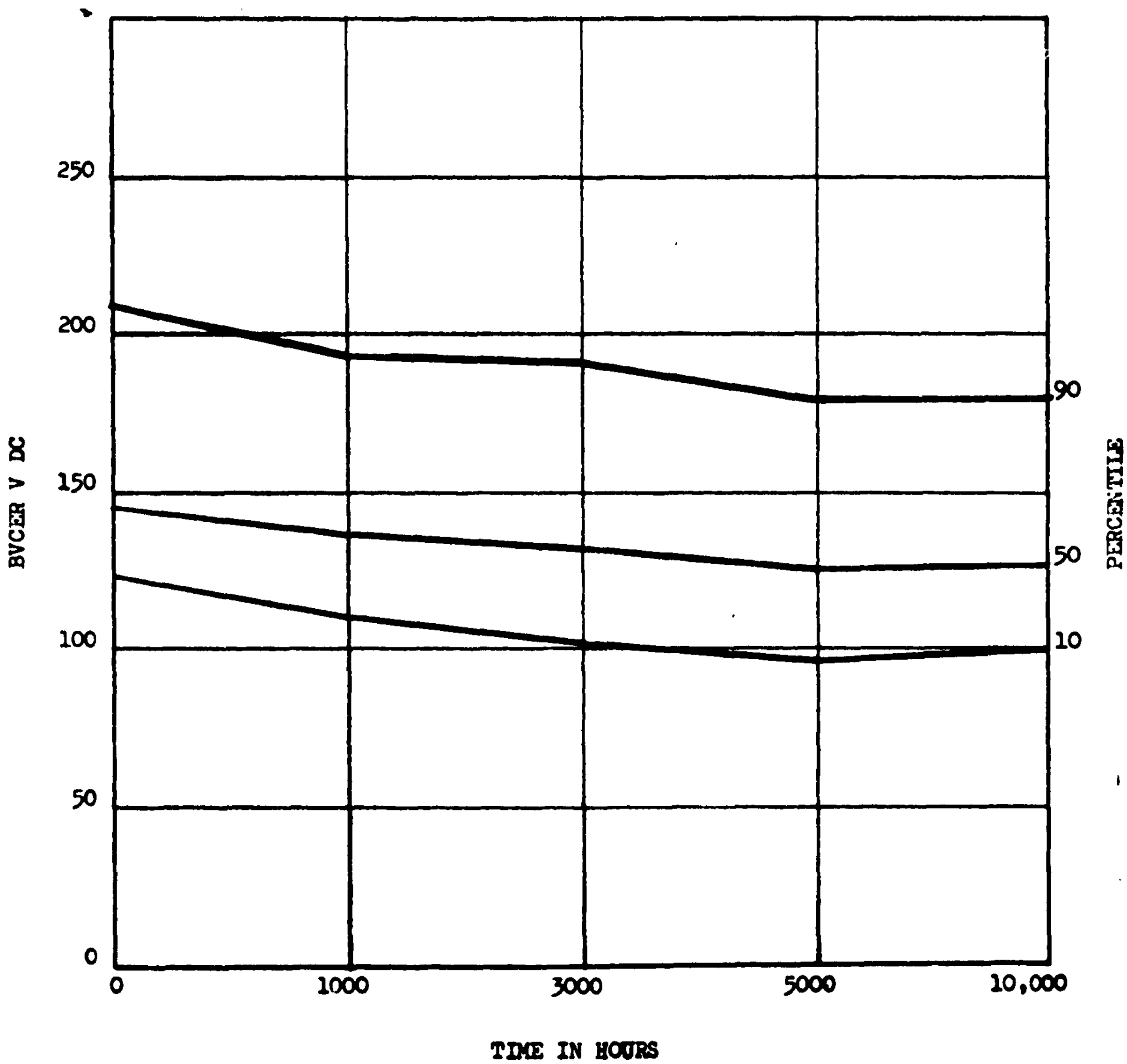
STRESS: STORAGE LIFE - 10,000 Hours at 110° C

PARAMETER: BVCER

TEST CONDITIONS: IC = -50 MA DC RBE = 100Ω

INITIAL LIMIT: -80 Vdc Min.

NUMBER OF UNITS: 100



THE BENDIX CORPORATION, SEMICONDUCTOR DIVISION

TRANSISTOR TYPE 2N1430

PARAMETER DISTRIBUTION

TYPE: 10 Ampere DAP

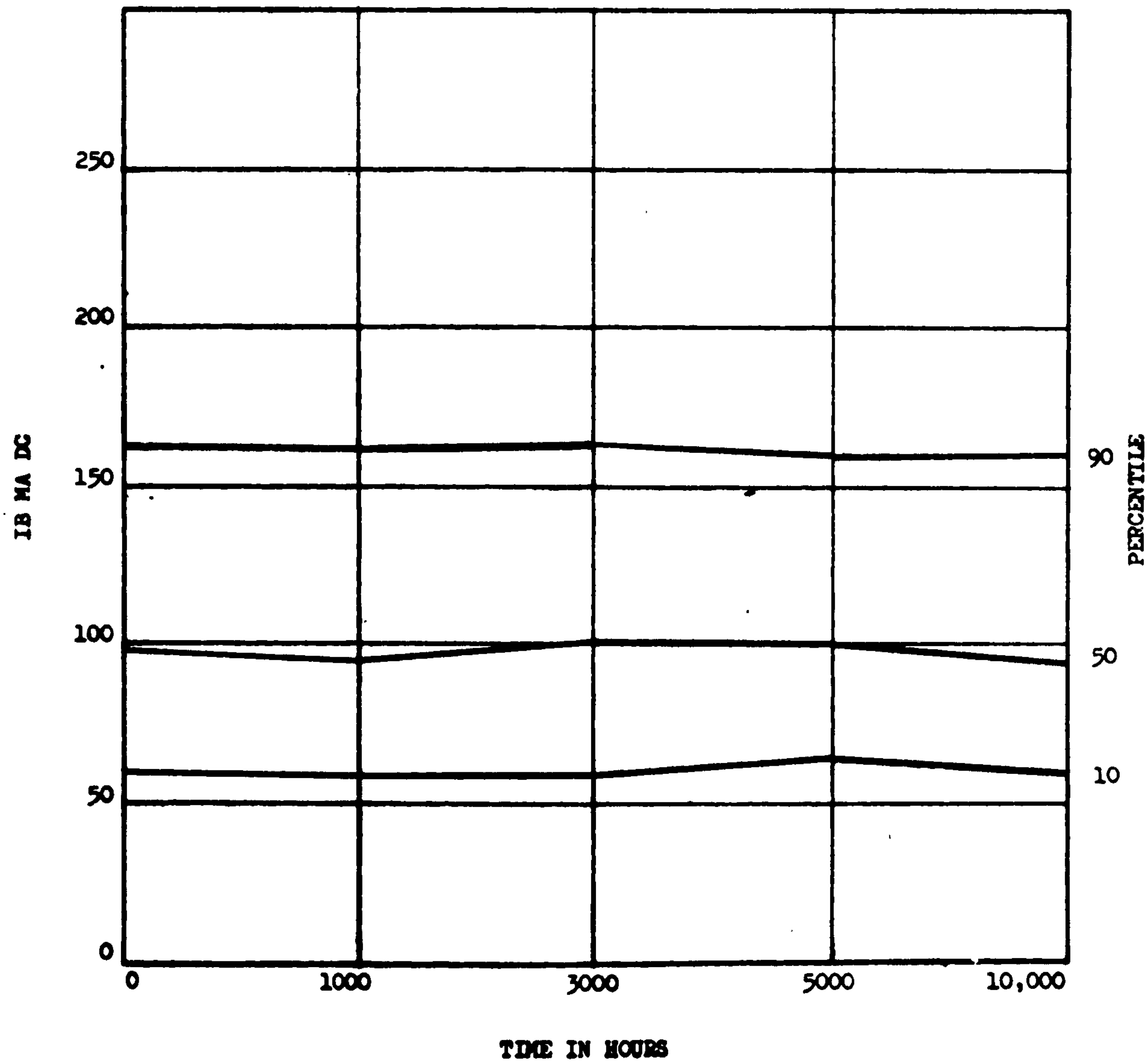
STRESS: STORAGE LIFE - 10,000 Hours at 110° C

PARAMETER: IB (h_{FE})

TEST CONDITIONS: VCE = -2Vdc IC = -5 Adc

INITIAL LIMIT: -50 MA DC Min. -165 MA DC Max.

NUMBER OF UNITS: 100



IV - APPENDIX III

Electrical Specifications

The 2N1430 is a switching transistor to be used with inductive, capacitive, or resistive loads. The revised 2N1430 specification reflects the improved technology of the 10 A DAP as well as a practical description of the device which is of importance to the design engineer using a switching transistor.

Electrical Parameters

The measured I_{CBO}'s are decreased or measured at a much higher voltage than in the original spec. In addition, I_{CBO} is measured at 100 V and 85°C which gives an indication of currents to be expected when operating at elevated junction temperatures.

A maximum gain at I_C = 10 A was specified. This is desirable for operation in inverters which is the major application of this transistor.

The saturation voltage and the open base breakdown voltage are improved. The V_{CER} parameter was replaced by I_{CES} in order to cover the two extreme cases of R_{BE} equal to zero and infinity.

The small signal h_{fe} at 100 Kc was not included because it does not help in designing switching circuits. A more realistic switching circuit for measuring rise, storage and fall time is used in the revised specification.

Safe Operating Areas

It is not sufficient to specify a safe operating area without limiting some other conditions simultaneously. The following conditions must be satisfied in order to achieve reliable operation:

Base Current

The base current is responsible for collector current concentration in the junction. The higher the base current, the higher the current concentration. Especially at positive base currents during switching through the peak power of 800 W where failures may occur unless I_B is equal to or less than 1.5A.

Driving Circuit Output Resistance

If a current source would be used to drive the transistor, the positive I_B would be independent of the input impedance of the transistor. For instance, if the peak power of 800 W is reached, I_B may be 1A which may initiate current concentration. By using a voltage drive and a maximum source resistance of 4 ohm, the I_B is decreasing after the storage time of the transistor. This enables the 2N1430 to absorb the peak power and ensures safe operation.

Maximum Junction Temperature and Power Dissipation

It is difficult, and in most cases, not practical to determine the instantaneous junction temperature. It must be considered that calculations give no indication of localized heating or current concentration in the transistor. Tests indicated that most transistors will not fail when the switching time is limited to the collector current fall time resulting from suddenly opening the base provided a certain average junction temperature is not exceeded. From experience, a maximum average junction temperature can be specified which can be easily calculated using average power dissipation.

Specifying a maximum average power dissipation limits automatically the maximum repetition rate at which transistors can be operated with a given peak power pulse. A longer collector current fall time increases the power dissipation during switching and therefore decreases the allowable frequency.

Switching Time Between Saturated State and Cutoff

Reducing the positive base current or changing the base current slowly from a negative to a positive value results in a long collector current fall time. The load line may not change considerably, however, the peak power is applied to the transistor for a longer time. The junction temperature of a transistor with certain thermal time constants may rise to such a value that the device may be destroyed or damaged. Therefore, the time in which the load line can be traversed must be limited. Similarly, switching from cutoff to saturation must be accomplished in a limited time if the load line is traversing high power points in the active region. In some inverter circuits and applications like TV-horizontal deflection circuits, the load line reaches into the area having positive collector currents. (See Figure 7). This operation in the reverse direction does not damage the transistor.

Derating

In special cases the switching time, maximum collector current, maximum base current, etc. may be exceeded. There are no standard rules or means of calculation available to derate the 2N1430. The maximum voltage given by the safe operating area should never be exceeded.

IV - APPENDIX IV (1.1.4.1)

Establishing Control Limits

From the data, the average range R was estimated at .31 mils.

Then $\hat{\sigma} = \bar{R}/d_2$ where

$\hat{\sigma}$ = estimate of standard deviation of the population

$\bar{R}$ = average range

d_2 = constant obtained from Q.C. Handbook, in this case 3.078

$\hat{\sigma}$ = .31/3.078 = .101 mils

Our sampling plan is based on variables. To obtain a given protection, it is important to find the distance away from the specification limits to which it is permissible to go. This distance is $U - k'^{*}\sigma$ and $L + k^{*}\sigma$ where

U = Upper specification

L = Lower specification

σ = standard deviation

k'^{*} = constant

L	← $k'^{*}\sigma$ →	The averages of samples must be in here	← $k'^{*}\sigma$ →	U

(1)

To obtain k'^{*} we go to tables prepared by Bowker and Goode , and partially reproduced in Grant(2) , where we find the following information.

"For a known-sigma plan for two-sided specifications and sample size n = 10 k'^{*} = 1.164". The table also tells us that this is essentially equivalent to a "single sampling plan by attributes with sample size n=30 and acceptance number c=3". This latter information shall be used in Appendix V.

To obtain our limits, therefore, we have

$k'^{*}\sigma = 1.164 \times .101 = .118$

$U - k'^{*}\sigma = 0.94 - .12 = 0.82$ mils (coded)

$L + k'^{*}\sigma = 0.46 + .12 = 0.58$ mils (coded)

<u>NOTE:</u> With the micrometer it is possible to read only to the tenth of a mil, and, therefore, when we have a split tenth we found off to the nearest tenth. That is why our upper specification limit U is called 0.94 instead of 0.90. An analogous argument holds for the lower limit L.

(1) A.H. Bowker and P.H. Goode "Sampling Inspection by Variables" McGraw-Hill, 1952
(2) E. L. Grant "Statistical Quality Control" McGraw-Hill, 1952 pgs. 542-543.

IV - APPENDIX V (1.1.4.3)

<u>Principles Underlying AOQL Sampling Plans.</u>

As indicated in Appendix IV, our sampling plan by variables is essentially equivalent to a single sampling plan by attributes with sample size n= 30 and acceptance number of c= 3. (Note that, in sampling by variables, we obtain essentially the same protection with a sample size of n= 10, thus cutting down inspection by about 2/3).

In order to obtain further results, it becomes necessary to develop the Operating Characteristic Curve (OC Curve) for the sampling plan. Briefly, the OC curve gives us the probability of accepting a lot having a given percent of defectives in it.

Let p = proportion of defectives in the submitted lot
n = sample size, in this case 30
Pa = probability of acceptance, as obtained from a Poisson Table (3)
c = acceptance number, in this case 3

By varying p, we can obtain the following table:

p	np=30p	Pa
.05	1.5	.934
.08	2.4	.779
.10	3.0	.647
.12	3.6	.515
.15	4.5	.342
.20	6.0	.151
.25	7.5	.059

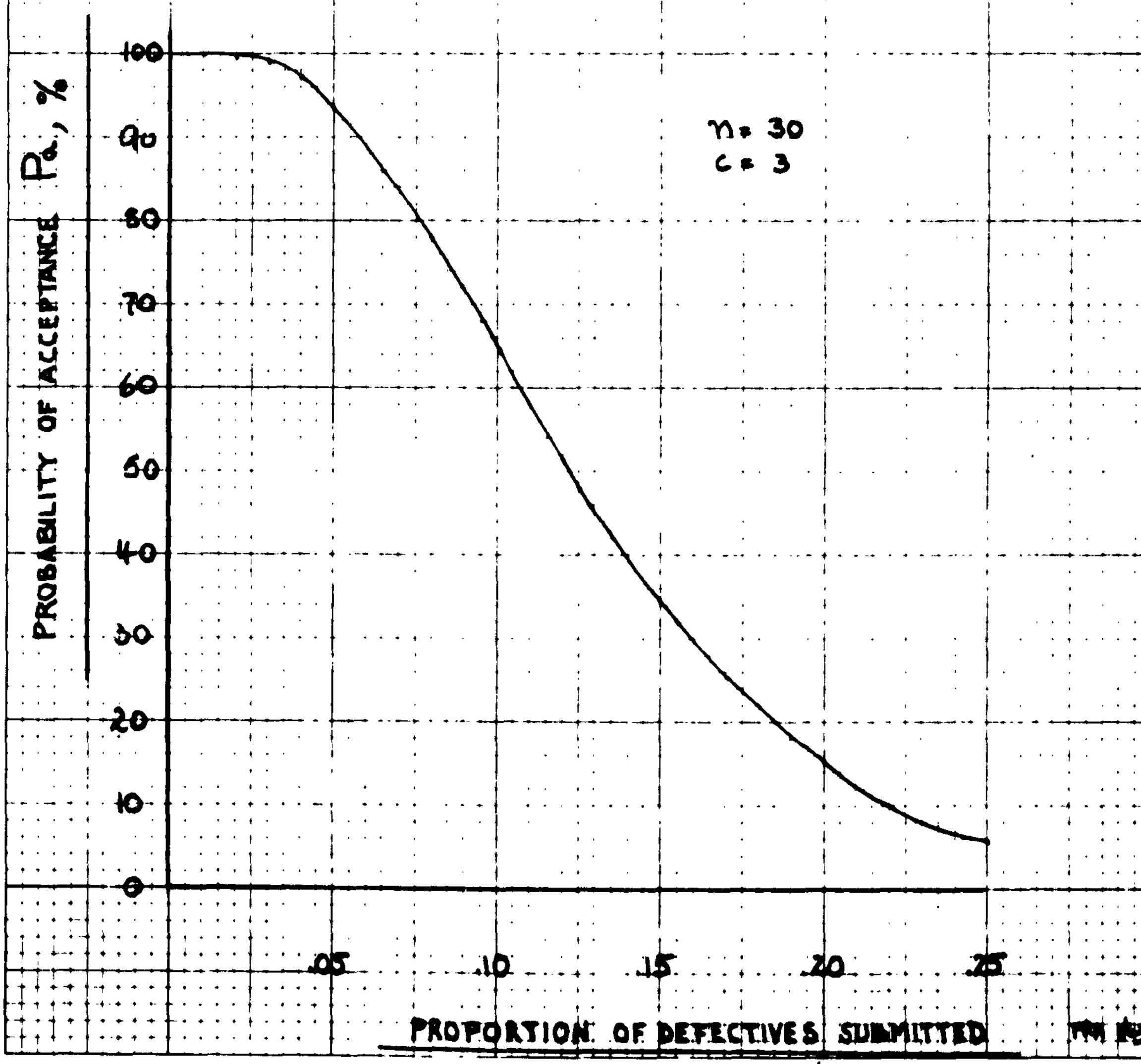
The OC curve thus evolved is shown in Figure A. From it, we can read the answer to question 1.1.4.3.3, namely: "What is our LTPD, or at what percent defective do we have a 90% chance of rejection?" The answer to this is that for 22% defectives Pa = .10 or 10%. Another way of putting it is to say that we will reject this quality or worse 90% of the time.

Let us now develop the equation giving us the average number of units inspected.

$$I = \underbrace{n}_{\text{\# inspected in every lot}} + \underbrace{(N - n)\quad(1 - Pa)}_{\text{additional \# inspected when a lot is rejected and screened 100\%.}} = \cancel{n}+N-NPa-\cancel{n}+nPa=N-(N-n)\,Pa \quad (1)$$

FIGURE A (APPENDIX V)

OC CURVE



V - IDENTIFICATION OF PERSONNEL

1.1 Personnel

The following changes were made during this period:

Added to contract:

Nussear, John G.

Deleted from contract:

Fallon, Dennis

NUSSEAR, JOHN G.

Fairmont State	B.S. Physics	1950
	B.S. Math.	
Fairleigh Dickinson U.	Graduate Studies, Business Management	

Mr. Nussear is Germanium Materials Manager, responsible for the transformation of the basic semiconductor material into a form usable for device fabrication. Prior to joining Bendix, he was Chief Engineer - Semiconductor Division for Tung-Sol Electric from 1960-1962, responsible for all technology. From 1956-1960, he served as Manager of the Design and Development Department responsible for new product and process development. From 1953-1956, he was responsible for materials engineering and was Assistant Manager of the Design and Development Department. From 1951-1953 was employed by the Radio Corporation of America as an applied physicist in the semiconductor Chemistry and Physics Laboratory.

1.2 Engineering Time

During this period 1345 hours were spent by Bendix personnel toward the fulfillment of the contractual commitments.